Rules and Regulations for the Classification of Offshore Units

Parts 1 to 11

July 2014

Lloyd's Register

Rules and Regulations for the Classification of Offshore Units

Part 1
Regulations

July 2014

Lloyd's
Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Offshore Units

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e., Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g., *see* 2.1.3 (i.e., down to paragraph).
(b) In same Part but different Chapter, e.g., *see* Ch 3,2.1 (i.e., down to sub-Section).
(c) In another Part, e.g., *see* Pt 5, Ch 1,3 (i.e., down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g., as shown in Fig. 2.3.5 (i.e., Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g., as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g., *see* Table 2.7.1 in Pt 3, Ch 2.

References to other sets of Rules and Regulations published by Lloyd's Register Group Limited:

> Criteria as detailed above have also been used when references are made to other sets of Rules, such as the *Rules and Regulations for the Classification of Ships*, (hereinafter referred to as the Rules for Ships) e.g., *see* Pt 6, Ch 1,3 of the Rules for Ships. References to Lloyd's Register's *Rules and Regulations for the Classification of Ships* within these Rules are of the same year of publication.

References to Standards and Codes:

> For undated references, e.g., IEC 60092-502, *Electrical installations in ships – Part 502: Tankers – Special features*, the latest edition of the referenced document (including any amendments) applies.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

July 2014

CLASSIFICATION OF OFFSHORE UNITS

Rules and Regulations

July 2014

UPDATE NOTES

1. The June 2013 version of these Rules and Regulations incorporates those changes contained in the Notices to the 2012 version.
2. Changes approved by the Board.
3. Editorial amendments have also been incorporated.
4. The July 2014 version of these Rules and Regulations supersedes the June 2013 version.

CLASSIFICATION

The following explanatory note is offered to assist those concerned in the application of these Rules and Regulations.

Explanatory Note

Unit classification may be regarded as the development and worldwide implementation of published Rules and Regulations which, in conjunction with proper care and conduct on the part of the Owner and Operator, will provide for:

1. the structural strength of (and where necessary the watertight integrity of) all essential parts of the hull and its appendages;
2. the safety and reliability of the propulsion and steering systems; and
3. the effectiveness of those other features and auxiliary systems which have been built into the unit in order to establish and maintain basic conditions on board whereby appropriate cargoes and personnel can be safely carried whilst the unit is at sea, at anchor, or moored in harbour.

Lloyd's Register Group Limited (LR) maintains these provisions by way of the periodical visits by its Surveyors to the unit as defined in the Regulations in order to ascertain that the vessel currently complies with those Rules and Regulations. Should significant defects become apparent or damages be sustained between the relevant visits by the Surveyors, the Owner and Operator are required to inform LR without delay. Similarly any modification which would affect Class must receive prior approval by LR.

A unit is said to be in Class when the Rules and Regulations which pertain to it have, in the opinion of LR, been complied with, or when special dispensation from compliance has been granted by LR.

It should be appreciated that, in general, classification Rules and Regulations do not cover such matters as the unit's floatational stability, life-saving appliances, pollution prevention arrangements, and structural fire protection, detection and extinction arrangements where these are covered by the *International Convention for the Safety of Life at Sea, 1974*, its Protocol of 1978, and the amendments thereto, nor do they protect personnel on board from dangers connected with their own actions or movement around the unit. This is because the handling of these aspects is the prerogative of the National Authority with which the unit is registered. A great many of these authorities, however, delegate such responsibilities to the Classification Societies who then undertake them in accordance with agreed procedures.

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Section 1

1.1 Lloyd's Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd's Register Group Limited, including but not limited to: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited. Lloyd's Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as 'LR'.

Section 2

2.1 Lloyd's Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;
appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register International)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany
(via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register International)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

Section 3

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd's Register Group Limited
- Chairman of the Classification Committee of Lloyd's Register Group Limited

Members Nominated by:

• Technical Committee	
• Royal Institution of Naval Architects	2
• Institution of Engineers and Shipbuilders in Scotland	2
• Institute of Marine, Engineering, Science and Technology	2
• Institute of Materials, Minerals and Mining	1
• Honourable Company of Master Mariners	2
• Institution of Engineering and Technology	1
• Institute of Refrigeration	1
• Welding Institute	1
• Shipbuilders' and Shiprepairers' Association	2
• The Society of Consulting Marine Engineers and Ship Surveyors	1
• Community of European Shipyards Associations	1
• Society of Maritime Industries	2
• European Marine Equipment Council	1
• Chamber of Shipping	1
• Greek Shipping Co-operation Committee	1
• International Association of Oil and Gas Producers	1

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.

(b) A maximum of five representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee under one of the categories identified in 3.1.

(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:

(a) any technical issues connected with LR's marine business;

(b) any proposed alterations in the existing Rules;

(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies these may be implemented by LR without consideration by the Technical Committee.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than Part 1, Chapter 1, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members

- Chairman and Chief Executive Officer of Lloyd's Register Group Limited

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee Chairman is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than Part 1, Chapter 1, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and

(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 5*

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the

date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as ‘Lloyd's Register’. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

8.4 Except in the circumstances of section 8.2 above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

List of abbreviations

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineers
BS	British Standard (issued by British Standard Institution)
DFF	Design Fatigue Factors
DP	Dynamic Positioning
ESD	Emergency Shut Down
ESDV	Emergency Shut Down Valve
FLNG	Floating LNG
FPSO	Floating Production, Storage and Off-loading installation
FRU	Floating Re-gasification Unit
FSRU	Floating Storage and Re-gasification Unit
FSO	Floating Storage and Offloading Vessel
FSU	Floating Storage Unit
GMDSS	Global Maritime Distress and Safety System
HCA	Helideck Certification Agency
IACS	International Association of Classification Societies
ILO	International Labour Organisation
IMO	International Maritime Organization
ISO	International Organisation for Standardisation
ISM Code	International Safety Management Code
LNG	Liquefied Natural Gas
LOLER	Lifting Operations and Lifting Equipment Regulations (UK)
MARPOL	International Convention on the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee (IMO)
MODU	Mobile Offshore Drilling Unit
MPI	Magnetic Particle Inspection
NACE	National Association of Corrosion Engineers
NDE	Non- Destructive Examination
NDT	Non-Destructive Testing
PWHT	Post Weld Heat Treatment
RP	Recommended Practice
RT	Radiographic Testing
SCF	Stress Concentration Factor
SIGTTO	Society of International Gas Tanker and Terminal Operators Ltd
SBM	Single Buoy Mooring
SCE	Safety Critical Element
SCR	Safety Case Regulations
SMS	Safety Management System
SOLAS	International Convention on the Safety of Life at Sea
SPM	Single Point Mooring
STCW	International Convention on Standards of Training, Certification and Watch-keeping for seafarers
TLP	Tension Leg Platform
WPS	Welding Procedure Specification

■ *Section 1*
Conditions for classification

1.1 Application

1.1.1 The *Rules and Regulations for the Classification of Offshore Units* (hereinafter referred to as the Rules for Offshore Units) are applicable to units engaged in offshore operations including drilling, oil/gas production and storage, accommodation and other support functions and which generally operate within the territorial waters of a Coastal State Authority but excluding the ship types defined in Part 4 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.1.2 An offshore unit may be assigned one of the two following class notations:

OI This notation is applicable to floating offshore installations that operate at a fixed geographic location for their entire service life, *see* 1.2.

The following asset types are covered by the **OI** notation:

- column-stabilised semi-submersible floating production units (FPU);
- self-elevating (jack-up) production units;
- jack up accommodation
- crude oil floating production, storage and offloading ship and barge type units;
- crude oil floating storage and offloading ship and barge type units;
- liquefied gas floating production and storage ship and barge type units;
- liquefied gas floating storage ship and barge type units;
- tension leg units;
- deep draught caisson units;
- buoys.

OU This notation is applicable to mobile offshore units that operate at and transit between different locations, *see* 1.3.

The following asset types are covered by the **OU** notation:

- column-stabilised semi-submersible units (mobile offshore drilling units, heavy lift vessels, accommodation units and diving support vessels);
- self-elevating (jack-up) mobile offshore drilling units;
- surface type units (drill ships, twin-hull heavy lift vessels);
- wind turbine installation vessels
- tender barge.

1.1.3 The following Parts, Chapters and Sections are only applicable to floating offshore installations at a fixed location:

- 1.2
- Part 1, Chapter 5.
- Part 3, Chapter 13.
- Part 3, Chapter 14.
- Part 9.
- Part 10.
- Part 11.

1.1.4 The following Parts, Chapters and Sections are only applicable to mobile offshore units:

- 1.3.
- Part 3, Chapter 5
- Part 3, Chapter 16.

1.2 Floating offshore installations at a fixed location

1.2.1 Floating offshore installations at a fixed location will be assigned the class notation **OI**.

1.2.2 The basic Lloyd's Register (LR) class notation for an installation would normally include:

- Description of the installation, facilities provided and field location.
- Structure and marine systems.
- Positional mooring system.
- Propulsion (where applicable).

Process facilities are not required to be classed; however, an optional class notation **PPF** (process plant facility) can be assigned at the request of the Owner, *see* 2.4.13. Detail design, procurement, construction, site integration and commissioning activities regarding topsides facilities are typically subject to certification by LR to recognised National and International Codes, or equivalent engineering standards. Alternatively, the topsides could be subject to verification to an agreed written scheme. These facilities will be installed on a vessel with a LR classed hull, marine systems and mooring system. Certification or verification of the topsides facilities is the minimum requirement for assignment of an LR class notation for a complete floating offshore installation. Other optional class notations are also given in Section 2.

1.2.3 As an option, the Owner may request that LR consider performance standards determined by risk assessment as the basis for design, construction, and inspection/maintenance. Guidelines for classification of an offshore installation using risk assessment to determine performance standards are provided in Chapter 5. Definitions of risk assessment terms are also given in Chapter 5. Performance standards determined by risk assessment may be accepted by LR as the alternative basis for classification, provided that:

- LR approval is obtained at all key stages detailed in Chapter 5; and
- LR verifies that all elements which are critical to the safety and integrity of the installation meet their required performance standards, as outlined in Chapter 5.

Where a Formal Safety Assessment or Safety Case is prepared as a requirement of a National Administration or of the Owner, the Owner may request that LR consider the results as a basis for determining the performance standards to be used for classification. In such cases, the Formal Safety Assessment or Safety Case will be reviewed by LR to confirm that it considers all hazards to the safety and integrity of the installation which are relevant to classification. The Guidelines in Chapter 5 will then apply.

1.2.4 For units which are outside the scope of application of the 2009 MODU Code and/or the international conventions referred to in 1.4.10, compliance with any prescribed standards of the applicable Coastal State Authority is to be demonstrated by the issue of appropriate certification by that Coastal State Authority or LR where so authorised.

1.2.5 LR classed tankers being converted for service as a floating offshore installation at a fixed location in accordance with the requirements of these Rules will be eligible for class notation **OI**. Special consideration will be given to the class notation assigned when the tanker to be converted is not classed with LR, *see also* Part 10.

1.3 Mobile offshore units

1.3.1 Mobile offshore units will be assigned the class notation **OU**.

1.3.2 The adequacy of sea bed conditions with respect to bearing capacity, resistance to possible sliding and anchor holding capacity is not covered by classification. In particular, for self-elevating units, it is the responsibility of the Owner to be satisfied that the sea bed conditions are suitable to allow the legs to be safely and adequately preloaded.

1.3.3 It is the Owner's responsibility to comply with any applicable regulations of the Coastal State Authorities in the areas of operation. Compliance with the prescribed standards of the applicable National Administration is to be demonstrated by the issue of appropriate certification by the National Administration or LR where so authorised. *See also* 1.4.11.

1.3.4 When accommodation and other support units are intended to operate for prolonged periods adjacent to other offshore installations which are being used for hydrocarbon exploration or production, it is the Owner's responsibility to

comply with the requirements of the appropriate National Administration and LR is to be advised at the approval stage so that classification aspects relating to safety are taken into account, *see* Part 7. Special consideration will be given to existing units with regard to class.

1.4 General

1.4.1 Offshore units built in accordance with LR's Rules and Regulations, or in accordance with requirements equivalent thereto, will be assigned a class on the *ClassDirect Live* website and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for materials, structure, machinery, equipment and other safety considerations.

1.4.2 Units designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being considered by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner's proposals at an early stage, in order that a basis for acceptance of the standards may be agreed.

1.4.3 The Classification Committee, in addition to requiring compliance with LR's Rules, or other agreed performance standards, may require to be satisfied that units are suitable for geographical or other limits or conditions of the service contemplated.

1.4.4 Although the specified design environmental criteria on which classification is based are the responsibility of the Owner, assessment by LR of a unit's suitability for service at a particular offshore location will be undertaken and agreed before approval.

1.4.5 Loading conditions and other preparations required to permit a unit (whether self-propelled or not) with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.4.6 Any damage, defect, breakdown or grounding, serious deficiency, detention or arrest, or refusal of access which could invalidate the conditions for which class has been assigned is to be reported to LR without delay.

1.4.7 The Owner is solely responsible for the operation of the unit. The Rules are framed on the understanding that the unit will be properly loaded and operated, and the environmental conditions are no more severe than those agreed for the design basis and approval, without prior agreement of LR.

1.4.8 When longitudinal strength calculations are required for ship units and other surface type units, loading guidance information is to be supplied to the Master by means of a Loading Manual and in addition, when required, by means of a loading instrument, *see also* 1.4.9. Loading Manuals and loading instruments for surface type units are to be in accordance with Pt 3, Ch 4,8 of the Rules for Ships.

1.4.9 It will be the responsibility of the Owner to provide instructions and set down limits for the operation of the unit to ensure that the loading and environmental conditions on which classification is based will not be exceeded. These instructions and limitations are to be contained in the Operations Manual (or a Loading Manual for ship units and other surface type units) which is to be retained on board the unit. The Owner should ensure that the Manual is kept up to date and contains appropriate data required by the relevant National Administration.

1.4.10 For units, the arrangements and equipment of which are required to comply with the requirements of the:

- *IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units, 2009* (2009 MODU Code);
- *Load Lines Convention*;
- *International Convention for the Safety of Life at Sea, 1974* and its Protocol of 1978;
- *International Convention for the Prevention of Pollution from Ships, 1973*, as modified by the Protocol of 1978 relating thereto;
- *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code); and applicable Amendments thereto.

  The Classification Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised. Safety Management Certificates in accordance with the provisions of the International Safety Management Code (ISM Code) may be issued by an organisation complying with IMO Resolution A.739(18) and authorised by the National Administration with which the unit is registered. Cargo Ship Radio Certificates may be issued by an organisation authorised by the National Administration with which the unit is registered. In the case of dual classed units, Convention Certificates may be issued by the other Society with which the unit is classed, provided that this is recognised in a formal Dual Class Agreement with LR and provided that the other Society is also authorised by the National Administration. In the event of a National Administration withdrawing any unit's Convention Certificate (referred to in this Section), then the Classification Committee may suspend the unit's class. If a unit is removed from the National Administration's Registry for non-compliance with the Conventions or Classification requirements referred to herein then the Classification Committee will suspend the unit's class. In the event of ISM Code certification being withdrawn from a unit or Operator, the Classification Committee will suspend the unit's class.

1.4.11 Where the National Administration has no prescribed standards for units which are outside the scope of application of the 2009 MODU Code and/or the International Conventions referred to in 1.4.10 or their standards are not considered acceptable for classification purposes, LR will apply the relevant parts of the 2009 MODU Code/Convention Regulations and other recognised Standards as applicable to the intended use of the unit as a prerequisite to classification.

1.4.12 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new unit or newly installed on an existing unit, then the system is to be certified in respect of longitudinal strength in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*.

1.4.13 Where an onboard computer system having stability computation capability is provided on a new unit, the system is to be certified in respect of stability aspects, in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the unit on which it is installed.

1.4.14 When a unit, fitted with a conventional rudder, is to operate for a prolonged period at a fixed location, it is the Owner's responsibility to ensure that suitable arrangements are provided to prevent damage to the steering gear. Special consideration will be given to the requirements for the steering gear and propelling machinery, *see* Pt 4, Ch 10, and Pt 5, Ch 6 and Ch 19.

1.4.15 Where a unit has been detained by Port State Control, the Owner is to advise LR immediately, in order to arrange the attendance of a Surveyor.

1.5 Interpretation of the Rules

1.5.1 The interpretation of the Rules is the sole responsibility, and is at the sole discretion, of LR. Any uncertainty in the meaning of the Rules is to be referred to LR for clarification.

1.5.2 In many instances, these Rules require that particular components, systems and equipment, etc., must also comply with applicable Sections of the Rules for Ships. Every effort has been made to avoid potential conflicting requirements; however, where such a conflict becomes apparent, the requirements of these Rules shall take precedence.

1.6 Advisory services

1.6.1 The Rules do not cover certain technical characteristics, such as stability, hull vibration, etc., but advice may be given on such matters without any assumption of responsibility for such advice.

1.7 Legislative verification

1.7.1 LR has been authorised by a number of National Administrations to carry out verification of offshore units and installations in accordance with statutory Regulations. Full details will be supplied to Owners and other interested parties on request. *See also* 2.8 and Chapter 4.

1.7.2 LR has also been authorised on behalf of National Administrations of a large number of nations to issue certain statutory, safety and other certificates. LR is willing to act, when requested, in respect of such certification.

1.7.3 When machinery and equipment are to comply with EC Directives, LR as a notified body can issue EC Type Certification in accordance with LR's appointment. Full details will be supplied to manufacturers and other interested parties on request.

■ *Section 2*
Definitions, character of classification and class notations

2.1 General definitions

For the purpose of class notations, the definitions given in 2.1.1 to 2.1.24 will apply.

2.1.1 **Accommodation unit** is a support unit whose primary function is to provide accommodation for more than twelve offshore personnel who are not crew members or passengers.

2.1.2 **Buoy units** are floating units used as a mooring facility for a ship or an offshore unit and are secured by a flexible tether or tethers to the sea bed.

2.1.3 **Clear water**. Water having sufficient depth to permit the normal development of wind generated waves.

2.1.4 **Coastal State Authority** is the Authority responsible for the safety standards of units operating in or adjacent to their territorial waters.

2.1.5 **Column-stabilised semi-submersible units** have working platforms supported on widely spaced buoyant columns. The columns are normally attached to buoyant lower hulls or pontoons. These units are normally floating types but can be designed to rest on the sea bed, *see also* 2.2.3.

2.1.6 **Deep draught caisson units** are floating units which operate at a deep draught in relation to their overall depth.

2.1.7 **Disconnectable units** are self-propelled floating units which normally operate at a fixed location but are designed to disconnect from their moorings in order to avoid hazards or extreme storm conditions.

2.1.8 **Fetch**. The extent of clear water across which a wind has blown before reaching the unit.

2.1.9 **Floating offshore installation**. For classification a floating offshore installation is an offshore unit, and its integral associated offshore mooring facility, that operates at a fixed geographic location for its entire service life. When the mooring facility is independent of the offshore unit, e.g., buoy or mooring tower, classification of the floating offshore installation will normally be subject to the buoy or mooring tower being classed separately by LR unless agreed otherwise by the Classification Committee, *see also* Part 3 and Pt 4, Ch 4.

2.1.10 **Mobile offshore unit**. For classification a mobile offshore unit is an offshore unit that operates at and transits between different locations.

2.1.11 **National Administrations** are those Authorities defined in 2.1.4 and 2.1.12.

2.1.12 **National Authority** is the Marine Authority in the country in which a unit is registered.

2.1.13 **Offshore unit** means a unit engaged in offshore operations including drilling, oil production and storage, accommodation and other support functions and which generally operates within the territorial waters of a flag state, but excluding the ship types defined in Part 4 of the Rules for Ships.

2.1.14 **Owner**. In the context of these Rules, the Owner is defined as the party responsible for the unit, including its operation and safety.

2.1.15 **Positional mooring**. Station-keeping by means of multi-leg mooring systems with or without thruster assistance. Other definitions for mooring facilities are contained in Pt 3, Ch 10.

2.1.16 **Reasonable weather**. Wind strengths of force six or less in the Beaufort scale, associated with sea states sufficiently moderate to ensure that green water is taken on board the unit's weather deck at infrequent intervals only, or not at all.

2.1.17 **Self-elevating units** are units which are designed to operate as sea bed-stabilised units in an elevated mode. These units have a buoyant hull with movable legs capable of raising the hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. *See also* 1.4.9.

2.1.18 **Self-propelled** means that the unit is designed for unassisted sea passages and is fitted with propelling machinery in accordance with LR Rules.

2.1.19 **Sheltered water**. Water where the fetch is six nautical miles or less.

2.1.20 **Ship units** are mono-hull surface type units engaged in production and/or oil/gas storage/offloading while permanently moored at offshore locations with a ship or barge hull form. Such units may be self-propelled or be built without primary propelling machinery.

2.1.21 **Support units** are units whose primary function is to support offshore installations. They are normally engaged in one or more of the following functions:

- crane operations, fire-fighting, diving operations, maintenance, construction, pipelaying and accommodation.

2.1.22 **Support vessel**. Alternative name for a support unit as defined in 2.1.21.

2.1.23 **Surface type units** are units with a ship or barge-type displacement hull of single or multiple hull construction intended for operation in the floating condition.

2.1.24 **Tension-leg units** are offshore units which are linked to a fixed foundation by means of tensioned mooring tethers or other parallel, near vertical, connections in such a manner that the unit is constrained to float at a draught greater than that consistent with its displacement when floating freely.

2.2 Modes of operation

2.2.1 A mode of operation is a condition or manner in which a unit may operate or function while on location or in transit. From the classification aspect, the modes of operation of a unit should include the following:

(a) **Operating condition**
The condition when a unit is on location, for the purpose of carrying out its primary design operations, and the combined environmental and operational loadings are within the appropriate design limits established for such operations. The unit may be either afloat or supported on the sea bed, as applicable.

(b) **Survival condition**
A severe storm condition during which a unit may be subjected to the most severe environmental loadings for which the unit is designed. Production, drilling or similar operations may have been discontinued due to the severity of the environmental loadings. The unit may be either afloat or supported on the sea bed, as applicable.

(c) **Transit condition**
All unit movements from one geographical location to another.

For ship units and other surface type units, the mode of operation will be defined by the loading conditions stated in the approved loading manual.

2.2.2 **Linked** means connected while operating to a single point mooring facility, fixed structure or otherwise attached or resting on the sea bed.

2.2.3 **Sea bed-stabilised** means designed to operate under normal operating and survival conditions while the footings, mat or pontoons rest on the sea bed.

2.3 Character symbols

2.3.1 All units, when classed, will be assigned one or more character symbols, as applicable. For the majority of floating offshore installations at a fixed location, the character assigned will be **✠OI 100AT** or **✠OI 100AT (1)**. For the majority of mobile offshore units, the character assigned will be **✠OU 100A1**.

2.3.2 A full list of character symbols for which offshore units may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new units constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Classification Committee.

✠ This distinguishing mark will be assigned, at the time of classing, to new units constructed under LR's Special Survey, in accordance with plans approved by another recognised classification society.

OI These character letters will be assigned to all units which have been built or accepted into Class in accordance with the requirements prescribed for floating offshore installations at a fixed location in LR's *Rules and Regulations the Classification of Offshore Units*.

OU These character letters will be assigned to all units which have been built or accepted into Class in accordance with the requirements prescribed for mobile offshore units in LR's Rules for Offshore Units.

100 This character figure will be assigned to all units considered suitable for operating at exposed locations offshore or for sea-going service.

A This character letter will be assigned to all units which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:

(a) Units having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with Pt 4, Ch 9 of the Rules.

(b) Units classed for special service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Classification Committee as suitable and sufficient for the particular service.

(c) Units equipped with a classed dynamic positioning system which has sufficient power, redundancy of components and duplication of controls to supplement or replace the anchoring equipment on board such that the combined system/equipment is approved by the Classification Committee as equivalent to the anchoring equipment necessary during voyages, transfer moves or under normal operating conditions, *see* Pt 3, Ch 9.

T This character letter will be assigned to floating offshore installations at a fixed location which have, in good and efficient condition, anchoring, mooring or linking equipment in accordance with the Rules, *see* Pt 3, Ch 10.

N This character letter will be assigned to installations on which the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

2.3.3 Non-propelled units which are required to make transit voyages from one operating site to another are to be fitted with towing arrangements in accordance with Pt 4, Ch 9.

2.3.4 Self-propelled units which are required by the Owners to make transit voyages from one operating location to another or are disconnectable to avoid severe storms or hazards are to comply with the requirements of 2.3.2 for the assignment of the character figure (**1**) which will be assigned after the character letter **T**.

2.3.5 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the unit will be liable to be withheld.

2.3.6 The character figure **100** will be omitted for units operating in protected waters such as harbours, inland lakes, etc., and the requirements of the Rules may be relaxed or otherwise amended as considered appropriate by the Classification Committee.

2.3.7 Units will not be classed unless the primary propelling machinery and/or the essential auxiliary machinery of the unit is also classed.

2.4 Class notations (hull/structure)

2.4.1 When considered necessary by the Classification Committee, or when requested by an Owner and agreed by the Classification Committee, a class notation will be appended to the character of classification assigned to the unit. This class notation will consist of one of, or a combination of, the following:

- A type notation.
- A special features notation.
- A special duties notation.
- A specified operating area.
- A service restriction notation.
- An operating limits notation.

2.4.2 **Type notation**. A notation indicating that the unit has been arranged and constructed in compliance with the particular Rules intended to apply to that type of unit, e.g., Mobile offshore drilling unit or Floating Production Unit. Typical type notations are defined in Part 3.

2.4.3 **Special duties notation**. A notation indicating that the unit has been designed, modified or arranged for special duties other than those implied by the type notation, e.g., oil exploration or well intervention. Units with special duties notations are not thereby prevented from performing any other duties for which they may be suitable.

2.4.4 **Special features notation**. A notation indicating that the unit incorporates special features which significantly affect the design, e.g., **DRILL** or **PPF**. *See* 2.4.13.

2.4.5 **Operating limits notation**. A notation indicating the significant design criteria on which approval of the unit is based, e.g.:

- Maximum operating environmental design limits for semi-submersible units and self-elevating units.
- Limiting sea state and/or wind speed during which a unit may remain moored to a single point mooring.

2.4.6 **Service restriction notation**. A notation indicating that the unit has been classed on the understanding that it will be operated only in suitable areas or conditions which have been agreed by the Classification Committee, e.g., protected waters service.

2.4.7 Service restriction notations will generally be assigned in the form shown in 2.4.9 and 2.4.10, but this does not preclude Owners requesting special consideration for other forms in unusual cases.

2.4.8 Where a service notation is applicable, certain exemptions may be granted. Where these affect statutory requirements, such as Load Lines, the Owner is to obtain the authorisation of the Flag State. Such exemptions are to be recorded on the Class certificate and any applicable statutory certificate.

2.4.9 **Protected waters service**. Service in sheltered water adjacent to sand banks, reefs, breakwaters or other coastal features.

2.4.10 **Specified operating area**. A notation indicating that the unit has been classed on the understanding that it will be operated only in suitable areas which have been agreed by the Classification Committee, e.g., North Sea service (Abbot Field) or Black Sea service.

2.4.11 A typical example of character of classification and class notations for a floating offshore installation at a fixed location is:

✠OI 100 AT floating production and oil storage installation, **PPF**, North Sea service (Abbot field).

A typical example of character of classification and class notations for a mobile offshore unit is:

✠OU 100A1 Mobile offshore drilling unit, **DRILL**, Oil exploration, Gulf of Mexico service.

2.4.12 The assigned character symbols of class and the appropriate class notations will be entered in the *ClassDirect Live* website. For all unit types except ship units and other surface type units, the limiting structural design criteria on which classification is based will also be entered on the *ClassDirect Live* website.

2.4.13 The following special features class notations may be assigned as considered appropriate by the Classification Committee:

PPF This notation will be assigned to units which have specialised structures and an installed process plant facility which has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations, *see* Pt 3, Ch 8.

DRILL This notation will be assigned to units which have specialised structures and an installed drilling plant facility which has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations, *see* Pt 3, Ch 7.

DROPS This notation will be assigned to units which have preventive measures to protect personnel from the hazards of dropped objects in accordance with Pt 3, Ch 7,10.

PM This notation will be assigned to mobile offshore units which have a positional mooring system which complies with the requirements of Pt 3, Ch 10.

PMC This notation will be assigned to mobile offshore units which have a positional mooring system for mooring in close proximity to other vessels or installations which complies with the requirements of Pt 3, Ch 10.

PRS This notation will be assigned to units which have a product riser system which has been constructed, installed and tested under LR's Special Survey, in accordance with LR's Rules, *see* Pt 3, Ch 12.

OIWS This notation for In-Water Survey may be assigned to a unit where the applicable requirements of LR's Rules and Regulations are complied with, *see* Pt 1, Ch 3,4.3, Pt 3, Ch 1,2.1.3 and Pt 8, Ch 1,1.3.

2.4.14 The application of the **OIWS** notation to existing units will be subject to special consideration by the Classification Committee.

2.4.15 **LI**. This notation will be assigned to surface type units where an approved loading instrument has been installed as a classification requirement.

2.4.16 Details of unit types and additional special features class notations for which special Rules apply are incorporated in Part 3, *see also* 2.8.

2.4.17 The following class notations may be assigned to ship units as considered appropriate by the Classification Committee:

(a) **ShipRight SDA**. This notation can be assigned to both new build ship units and tanker conversions when structural strength of the hull has been assessed for environmental loads assuming unrestricted service as a ship. The structural strength of the hull is to be verified using the finite element method.

(b) **ShipRight RBA.** The response based analysis (structure) class notation will be assigned to both new build ship units and tanker conversions when structural strength has been verified by performing direct calculations (finite element analysis) for hull structure in accordance with the *ShipRight Procedure for Ship Units*.

(c) **ShipRight FDA (years).** The fatigue design assessment (design life) class notation will be assigned to both new build ship units and tanker conversions when fatigue life of critical connection details has been assessed in accordance with the *ShipRight Procedure for Ship Units*.

(d) **ShipRight CM**. The construction monitoring class notation will be assigned to new build ship units and tanker conversions when agreed enhanced inspection measures have been implemented and verified during construction to ensure that at critical locations the connection details are within the agreed tolerances. Critical locations are to be agreed with LR on a case by case basis. A plan showing critical locations is to be submitted for approval, in accordance with the *ShipRight Procedure for Ship Units*.

(e) **CSR.** This notation indicates that the structure has been verified as fully compliant with IACS CSR. This notation cannot be assigned retrospectively. It may only be assigned to new build units or units which already had a **CSR** notation assigned before conversion or redeployment.

Assignment of these notations will be project-specific and will depend on whether the unit is a new build or tanker conversion, whether the unit is permanently moored or disconnectable and the site-specific environmental conditions, *see* Table 2.4.1. The design procedures given in the *ShipRight Procedure for Ship Units*, are required to be applied for hull strength, fatigue and construction aspects. Assignment of these notations will be specially considered for other surface type units.

Table 2.4.1 Application of ShipRight Notations

ShipRight notation	Redeployment and conversion		New build	
	Moderate environment	Harsh environment	Moderate environment	Harsh environment
RBA	Either **RBA** or **SDA** is required	Mandatory	Either **RBA** or **SDA** is required	Mandatory
FDA (years)	Mandatory	Mandatory	Mandatory	Mandatory
CM	Mandatory	Mandatory	Mandatory	Mandatory
SDA	Either **RBA** or **SDA** is required	N/A	Either **RBA** or **SDA** is required	N/A

2.4.18 The **ShipRight SDA** notation may be retained by LR Classed tankers after conversion to a floating offshore installation at a fixed location for service in a moderate environment as defined in Pt 10, Ch 1,1.2.3 and 2.4.15.

2.4.19 Special consideration will be given to assignment of additional notations given in Pt 1, Ch 2 of the Rules for Ships at the request of the Owner. The assignment of such notations will be conditional on compliance with all applicable requirements relevant to the unit type and service.

2.5 Class notations (machinery)

2.5.1 The following class notations are associated with machinery construction and arrangements, and may be assigned as considered appropriate by the Classification Committee:

✠OMC This notation will be assigned to non-propelled units when the essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR Rules.

[✠]OMC This notation will be assigned to non-propelled units when:

- the pressure vessels and electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules.
- other items of machinery and electrical power generation and other auxiliary machinery for essential services are in compliance with LR's Rules and supplied with the manufacturer's certificate.
- the system arrangement of essential auxiliary machinery is appraised and found to be acceptable to LR.

OMC This notation (without ✠) will be assigned to existing non-propelled units that will be accepted or transferred into LR class when:

- the essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey.
- the existing machinery installation and arrangement have been tested and found to be acceptable to LR.

✠LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR Rules.

[✠]LMC This notation will be assigned to self-propelled units when:

- the propelling arrangements for propellers, propulsion shafting and multiple input/output gearboxes, steering systems, pressure vessels and electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules.
- other items of machinery and gearing arrangements for propulsion and electrical power generation and other auxiliary machinery for essential services are in compliance with LR Rules and supplied with the manufacturer's certificate.
- the system arrangements of propelling and essential auxiliary machinery are appraised and found to be acceptable to LR.

LMC This notation (without ✠) will be assigned to existing self-propelled units that will be accepted or transferred into LR class when:
- the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey.
- the existing machinery installation and arrangement have been tested and found to be acceptable to LR.

IGS This notation will be assigned, when a unit having facilities for the storage of crude oil in bulk is fitted with an approved system for producing gas for inerting the crude oil storage tanks.

2.5.2 The following class notations are associated with the machinery control and automation, and may be assigned as considered appropriate by the Classification Committee:

UMS This notation may be assigned when the arrangements are such that the unit can be operated with the machinery spaces unattended. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

ICC This notation may be assigned when the arrangements are such that the control and supervision of the unit's operational functions are computer based. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

IP This notation may be assigned to a unit classed with LR when the arrangements of the machinery are such that the propulsion equipment and all the essential auxiliary machinery is integrated with the power unit for operation under all normal sea-going and manoeuvring conditions. The system is to be bridge controlled and the propulsion equipment is to incorporate an emergency means of propulsion in the event of failure in the prime mover. It also denotes that the machinery and control equipment has been arranged, installed and tested in accordance with LR's Rules.

2.5.3 The following special features class notations are associated with dynamic positioning arrangements and may be assigned as considered appropriate by the Classification Committee, *see* Pt 3, Ch 9:

DP(CM) This notation may be assigned when a unit is fitted with centralised remote manual controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules or is equivalent thereto.

DP(AM) This notation may be assigned when a unit is fitted with automatic main and manual standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules or that it is equivalent thereto.

DP(AA) This notation may be assigned when a unit is fitted with automatic main and automatic standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

DP(AAA) This notation may be assigned when a unit is fitted with automatic main and automatic standby controls for position keeping, together with an additional/emergency automatic control unit located in a separate compartment and with position reference systems and environmental sensors. It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or that it is equivalent thereto.

2.5.4 The dynamic positioning notations in 2.5.3 can be supplemented with a Performance Capability Rating notation (**PCR**). This rating indicates the calculated percentage of time that a unit is capable of holding heading and position under a standard set of environmental conditions (North Sea), *see* Pt 3, Ch 9.

2.5.5 Machinery class notations will not be assigned to units the hull/structure of which is not classed or intended to be classed with LR.

2.5.6 The notations ✠**LMC**, **[✠]LMC** and **LMC** (without ✠) will not, in general, be assigned to non-self-propelled vessels.

2.5.7 Special consideration will be given to assignment of the additional notations given in Pt 1, Ch 2 of the Rules for Ships, at the request of the Owner. The assignment of such notations will be conditional on compliance with all applicable requirements relevant to the unit type and service.

2.6 Lifting Appliances

2.6.1 *See* Pt 3, Ch 11, Table 11.

2.7 Class notations (environmental protection)

2.7.1 The following class notations are associated with the design and operation of a unit and may be assigned as considered appropriate by the Classification Committee, on application from the Owners, *see* Pt 7, Ch 11 of the Rules for Ships:

ECO This notation will be assigned when a unit is designed and operated in accordance with the relevant requirements of the Rules for Ships.

ECO (TOC) This notation will be assigned when the environmental protection arrangements are in accordance with the requirements of another recognised classification society and are essentially equivalent to Rule requirements and the unit is operated in accordance with the relevant requirements of the Rules for Ships.

2.7.2 The class notations defined in 2.6.1 will be suspended on change of Owner or Manager until LR can confirm by audit that the necessary operational procedures required by the Rules for Ships are established.

2.8 Class notation (Verification Schemes)

2.8.1 When an Owner requests classification based on a Formal Safety Assessment, *see* 1.2.3, and verification is carried out by LR in accordance with the Regulations of a National Administration and the Guidelines in Chapter 5, the class notation **CAV** may also be assigned to classed installations as considered appropriate by the Classification Committee.

2.9 Descriptive notes

2.9.1 In addition to any class notations, appropriate descriptive qualification notes may be entered on the *ClassDirect Live* website indicating the type of unit in greater detail than is contained in the class notation, and/or providing additional information about the design and construction, e.g., semi-submersible. A descriptive qualification is not a LR classification notation and is provided solely for information. Examples of descriptive notes are:

Semi-submersible	
Tanker conversion	Unit based on converted tanker
Turret mooring	Turret mooring (internal/external)
Spread mooring	Multi-point positional mooring
Disconnectable unit	Unit can be disconnected from fixed mooring
Helideck	Helicopter deck approval
COW (LR)	Crude oil washing certified by LR
SBT (LR)	Segregated ballast tanks certified by LR.

2.9.2 When a notation is assigned in accordance with 2.7, a descriptive note will also be added on LR's *ClassDirect Live* website to indicate the applicable National Administration, e.g., Norwegian Verification (**N**), United Kingdom Verification (**UK**).

2.9.3 Where an approved loading instrument is provided as an Owner's requirement, a descriptive note **LI** may be entered on the *ClassDirect Live* website.

2.9.4 Where LR's ShipRight procedures for the following have been applied on a voluntary basis to surface type units, a descriptive note will, at the Owner's request, be entered on the *ClassDirect Live* website, *see also ShipRight Procedures Overview* and Pt 1, Ch 2 of the Rules for Ships:

ES	Enhanced Scantlings
SEA (HSS-n)	Ship Event Analysis (Hull Surveillance Systems)
SERS	Ship Emergency Response Service
SCM	Screwshaft Condition Monitoring
MCM	Machinery Condition Monitoring
MCBM	Machinery Condition Based Maintenance
MPMS	Machinery Planned Maintenance Scheme
RCM	Reliability Centred Maintenance
BWMP	Ballast Water Management Plan.

2.9.5 Where evidence exists that supporting calculations have been performed in accordance with hull structural finite element and fatigue analysis procedures of a recognised Classification Society, then, on application from Owners, the descriptive note **ShipRight (E)** may be entered on the *ClassDirect Live* website.

2.9.6 Where an Owner elects to undertake hull Special Survey in accordance with the requirements of Pt 1, Ch 3,7 of the Rules for Ships, the descriptive note **ESP** may be entered on the *ClassDirect Live* website.

■ *Section 3* Surveys – General

3.1 Statutory surveys

3.1.1 The Classification Committee will act, when authorised on behalf of National Administrations, in respect of national and international statutory safety and other requirements for offshore units.

3.1.2 The Classification Committee will also act, when authorised, in respect of national safety, coastal state regulations relating to offshore units used for the exploration and exploitation of hydrocarbons.

3.2 New construction surveys

3.2.1 When it is intended to build a unit for classification with LR, constructional plans and all necessary particulars relevant to the hull/structure, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of LR before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

3.2.2 Where the proposed construction of any part of the hull/structure or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be assigned.

3.2.3 The materials used in the construction of the hull/structure and machinery intended for classification are to be of good quality and free from defects and are to be tested in accordance with the requirements of the Rules for Materials. The steel is to be manufactured by an approved process at an approved works. Alternatively, tests will be required to demonstrate the suitability of the steel.

3.2.4 Materials used in the construction of drilling and process plant are to comply with 3.2.3 and with the requirements of Part 3, *see also* 3.2.12.

3.2.5 New units intended for classification are to be built under LR's Special Survey. From the commencement of work until the completion of the unit, the Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.6 For compliance with 3.2.5, LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems. The minimum requirements for the approval of any such proposed Quality Assurance methods are laid down in Pt 4, Ch 11.

3.2.7 Copies of approved plans (showing the unit as built), essential certificates and records, the Operations Manual and loading and other instruction manuals are to be readily available for use when required by the attending Surveyors, and may be required to be kept on board.

3.2.8 When the machinery and drilling/process plant of a unit are constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

3.2.9 When remote and/or automatic control equipment, alarms and safeguards are fitted to the machinery and drilling/process plant, and riser systems the equipment is to be arranged, installed and tested in accordance with LR's Rules and Regulations.

3.2.10 The date of completion of the Special Survey during construction of units built under LR's inspection will normally be taken as the date of build to be entered on the *ClassDirect Live* website. If the period between launching and completion or commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated on the *ClassDirect Live* website.

3.2.11 When a unit, upon completion, is not immediately commissioned but is laid up for a period, the Classification Committee, upon application by the Owner prior to the unit being commissioned, will direct an examination to be made on site or in dry dock by the Surveyors. If, as a result of such survey, the structure, equipment and machinery are reported in all respects in accordance with applicable Rule requirements, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

3.2.12 Where classification is to be based on a formal safety case approach, *see* 1.4.3, special consideration will be given by LR to the use of materials in accordance with internationally recognised Codes and Standards, *see* 3.2.3.

3.3 Existing units

3.3.1 **Classification of units not built under survey**. The requirements of the Classification Committee for the classification of units which have not been built under LR's Survey are indicated in Ch 3,19. Special consideration will be given to units transferring class to LR from another recognised Classification Society.

3.3.2 **Reclassification**. When reclassification or class reinstatement is desired for a unit for which the class previously assigned by LR has been withdrawn or suspended, the Classification Committee will direct that a survey appropriate to the age of the unit and the circumstances of the case be carried out by the Surveyors. If, at such survey, the unit is found or placed in a condition in accordance with the requirements of the Rules and Regulations, the Classification Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

3.3.3 The Classification Committee reserves the right to decline an application for classification or reclassification where the prior history of condition of the unit indicates this to be appropriate.

3.3.4 **Unscheduled surveys**. Where the Classification Committee has concern about the condition of the unit and/or the equipment, an unscheduled survey may be required at any time to determine the actual condition.

3.4 Damages, repairs and alterations

3.4.1 All repairs to hull/structure, equipment, machinery and drilling/process plant which may be required in order that a unit may retain its class, *see* 1.4.6, are to be carried out to the satisfaction of the Surveyors. Alternatively, the Classification Committee may agree, in exceptional cases, that quality control can be enforced by the Owner or repairer, on site, in which case the repairs are to be surveyed by the Surveyors at the earliest opportunity thereafter.

3.4.2 When, at any survey, the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Classification Committee by the Surveyors.

3.4.3 When, at any survey, it is found that any damage, defect or breakdown, *see* 1.4.6, is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Classification Committee for consideration.

3.4.4 If a unit which is classed with LR is damaged to such an extent as to necessitate towage outside port limits whilst in a damaged condition to a suitable repair facility, it shall be the Owner's responsibility to notify LR at the first practicable opportunity.

3.4.5 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull/structure, equipment, machinery or drilling/process plant are to be submitted for approval, and such alterations are to be carried out to the satisfaction of the Surveyors.

3.5 Existing installations – Periodical Surveys

3.5.1 Annual Surveys are to be held on all units within three months, before or after each anniversary of the completion, commissioning or Special Survey, in accordance with the requirements given in Chapter 3. The date of the last Annual Survey will be recorded on the *ClassDirect Live* website.

3.5.2 Intermediate Surveys are to be held on all units instead of the second or third Annual Survey after completion, commissioning or Special Survey, in accordance with the requirements given in Ch 3,3. The Intermediate Survey may be commenced at the second Annual Survey and progressed with completion at the third Annual Survey. The date of the last Intermediate Survey will be recorded on the *ClassDirect Live* website. The concurrent crediting of items towards both Intermediate Survey and Special Survey is not permitted.

3.5.3 The Owner should notify LR whenever a unit can be examined in dry dock or on a slipway. A minimum of two Docking Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. The Classification Committee will accept In-Water Surveys in lieu of Docking Surveys on units assigned an **OIWS** (In-Water Survey) notation, *see* Ch 3,4.3.

3.5.4 One of the two Docking Surveys or In-Water Surveys in lieu of Docking Surveys required in each five-year period is to coincide with the Special Survey, *see* 3.5.3. Consideration may be given in exceptional circumstances to an extension of this interval not exceeding three months beyond the due date. In this context 'exceptional circumstances' means unavailability of dry-docking facilities, repair facilities, essential materials, equipment or spare parts or delays incurred by action taken to avoid severe weather conditions.

3.5.5 The date of the last examination in dry dock or In-Water Survey will be recorded on the *ClassDirect Live* website.

3.5.6 Attention is to be given to all relevant statutory requirements of the National Authority/Coastal State Authority in the country in which the unit is registered and/or is to operate.

3.5.7 When LR is to carry out verification on behalf of a National Authority, classification surveys required by the Rules, will, where practicable, be combined, and aligned, with the surveys required by the National Authority.

3.5.8 All units classed with LR are also to be subjected to Special Surveys in accordance with the requirements given in Ch 3,5. These surveys become due at five-yearly intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded on the *ClassDirect Live* website, and thereafter five years from the date recorded for the previous Special Surveys. *See also* 3.2.10. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed, the next period of hull classification will start from the date of the Special Survey before the extension was granted. A definition of 'exceptional circumstances' is given in 3.5.4.

3.5.9 Special surveys may be commenced at the fourth Annual Survey after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey. As part of the preparation for the Special Survey, the thickness determination, where applicable, may be dealt with in connection with the fourth Annual Survey.

3.5.10 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, if such work is to be credited towards the Special Survey. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases, the date recorded will be the fifth anniversary.

3.5.11 At the request of an Owner, it may be agreed that the Special Survey of the hull/structure be carried out on the Continuous Survey basis, where all compartments of the hull are to be opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular Special Survey of the hull/structure must be completed by the end of the five-year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in Ch 3,2.2.10, 2.2.11, 2.6 and Ch 3,3.2.3, 3.2.4, 3.2.6, 3.2.8, 3.2.9 and 3.2.11, the intervals for inspection will require to be specially agreed. Units which have satisfactorily completed the cycle will have the date of completion entered on the *ClassDirect Live* website, which will not be later than five years from the last assigned date of complete Survey of the hull/structure. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Classification Committee.

3.5.12 The Owner is to prepare a planned survey programme for the inspection of the hull/structure after each Special Survey, before the next Annual Survey is due. The survey programme is to cover the requirements for Annual Surveys, Intermediate Surveys, Special Periodical Surveys, Special Continuous Surveys, Docking Surveys and In-Water Surveys in lieu of Docking Surveys and is to be submitted to LR for review. A copy is to be kept on board and made available to the Surveyor. The survey programme should include plans, etc., for identifying the areas to be surveyed, the extent of hull cleaning, locations for non-destructive examination (including NDE methods), nomenclature, and methods for the recording of any damage or deterioration found. The planned survey programme, as agreed by LR, will be subject to revision if it is found to be necessary at subsequent surveys, or when required by the Surveyor. *See* Ch 3,1.6.

3.5.13 The requirements for survey and the schedule of surveyable items may be amended when any variation in service duties, usage or change in type notation is proposed, by agreement between the Owner and the Classification Committee.

3.5.14 Machinery is to be subjected to the surveys detailed in Ch 3,6 to Ch 3,12.

3.5.15 Drilling/process plant, safety and communication systems and hazardous areas are to be subjected to the surveys detailed in Ch 3,13, 14 and 16.

3.5.16 Complete Surveys of machinery and drilling/process plant become due at five-yearly intervals, the first one from the date of build or date of first classification as recorded on the *ClassDirect Live* website and thereafter five years from the date recorded in the Survey records for the previous complete survey. Consideration can be given at the discretion of the Classification Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before the extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Classification Committee. On satisfactory completion of a survey, an appropriate entry will be made in the Survey Records. Where the survey is completed more than three months before the due date, the new date recorded will be the final date of survey. In all other cases, the date recorded will be the fifth anniversary.

3.5.17 Upon application by an Owner, the Classification Committee may agree to the extension of the survey requirements for main engines which, by the nature of the unit's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 3.5.16.

3.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

3.5.19 When, at the request of an Owner, it has been agreed by the Classification Committee that the Complete Survey of the machinery and/or drilling/process plant may be carried out on the Continuous Survey basis, the various items of machinery and plant are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one fifth of the machinery and plant is to be examined each year. A record indicating the date of satisfactory completion of the Continuous Survey cycle will be made in the Survey Records.

3.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to the Surveyor's satisfaction.

3.5.21 Upon application by an Owner, the Classification Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the unit followed by a limited confirmatory survey carried out later by an Exclusive Surveyor. Particulars of this arrangement may be obtained from LR. Where an approved planned maintenance scheme is in operation, the confirmatory surveys may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from LR.

3.5.22 Where condition monitoring equipment is fitted, the Classification Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

3.5.23 The survey of boilers and other pressure vessels and the examination of steam pipes and Screwshaft Surveys are to be carried out as stated in Ch 3,10 to Ch 3,12.

3.5.24 The survey of pressure vessels for process and drilling plant is to be carried out as stated in Ch 3,17.

3.5.25 Where any inert gas system is fitted for the protection of storage tanks on board a unit intended for the storage of crude oil in bulk, the system is to be surveyed annually in accordance with the requirements of Ch 3,2.6. In addition, on units to which an **IGS** notation has been assigned, a Special Survey of the inert gas plant is to be carried out at intervals not exceeding five years, in accordance with the requirements of Ch 3,18.

3.5.26 Where the unit is fitted with a dynamic positioning system, the system is to be examined and tested annually, in accordance with the requirements of Ch 3,2.3.15. In addition, a Special Survey is to be carried out at intervals not exceeding five years, in accordance with Ch 3,6.2.10.

3.5.27 Where the Committee has agreed to an Owner's request to assign the notation 'laid-up', the unit may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey due date and an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date.

3.6 Certificates

3.6.1 When the required reports, on completion of the survey of new or existing units which have been submitted for classification, the required reports have been received from the Surveyors and classification has been agreed by the Classification Executive, a certificate of Classification may be issued by an authorised Surveyor. After approval by the Classification Committee, a certificate of First Entry of Classification, signed by LR's Chairman or the Chairman of the Classification Committee, will be issued to Builders or Owners.

3.6.2 A Certificate of Class valid for five years subject to endorsement for Annual and Intermediate Surveys will also be issued to the Owners.

3.6.3 LR Surveyors are permitted to issue provisional (interim) certificates to enable an offshore unit classed with LR to proceed on its voyage or to continue in service, provided that, in their opinion, the unit is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for continuance of class, but in all cases are subject to confirmation by the Classification Committee.

3.6.4 The full class notation and abbreviated descriptive notes shall be stated on the Certificate of Class and the provisional (interim) certificates.

3.6.5 Under no circumstances is the extension of validity of a class certificate to be granted beyond the due date of a Periodical Survey without the essential inspection (including NDE) having been completed for all prescribed parts of the primary structure.

3.7 Notice of surveys

3.7.1 It is the responsibility of the Owner to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Classification Committee. Information is available to Owners on the *ClassDirect Live* website.

3.7.2 LR will give timely notice to an Owner about forthcoming surveys, by means of a letter or a computer printout of a unit's Quarterly Listing of Surveys, Conditions of Class and Memoranda. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the *ClassDirect Live* website.

3.8 Temporary suspension of class

3.8.1 When an Owner intends to move a classed unit, whether self-propelled or not, to a new operating area and, due to the unit's significant design criteria, it is not suitable for exposed sea passages outside its normal operating area, the certificate of class will automatically be suspended during sea voyages. Class will be reinstated provided that the environmental criteria for the new area do not exceed the design criteria, and that an inspection by LR Surveyors when the unit arrives in the new area establishes that the hull/structure has suffered no damage in transit and remains in an efficient condition.

3.8.2 Self-propelled units which are disconnectable in order to avoid severe storm conditions or hazards will automatically remain in class and the certificate of class will be endorsed accordingly provided the environmental criteria for the proposed sea voyages do not exceed the design criteria. Reinstallation is to be subject to inspection by LR Surveyors.

3.8.3 When it is contemplated to tow a unit to an area which is outside the normal operating area of the unit, the towing arrangements are to be approved and certified by a competent authority for the particular voyage.

3.8.4 Although it is not generally a condition of class that the assessment of a unit as being fit for a particular sea passage should be undertaken by LR, when requested, LR is prepared to advise on the measures to be adopted for such a voyage, to supervise their execution and to issue the appropriate certificates.

3.8.5 All units will remain in class during location moves (i.e., moves within the same operational area) provided that:
(a) approved procedures stated in the unit's Operations Manual are adhered to;
(b) the towing arrangements and equipment on non-propelled units are to comply with Pt 4, Ch 9,2; and
(b) reports of any inspections of critical areas carried out during such moves are retained for review, where appropriate, by the Surveyors.

3.9 Withdrawal/suspension of class

3.9.1 When the class of a unit, for which the Regulations with regard to surveys on hull/structure, equipment and machinery have been complied with, is withdrawn by the Classification Committee as a result of a request from the Owner, the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

3.9.2 When the Regulations with regard to survey on the hull/structure, equipment, machinery or the drilling/process plant have not been complied with and the unit thereby is not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation will be assigned.

3.9.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey is not completed within three months of the due date of the survey.

3.9.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed, *see* 3.5.8, or is not under attendance by the Surveyors with a view to completion prior to resuming operations.

3.9.5 When, in accordance with 3.4.3 of the Regulations, a condition of class is imposed, this will be assigned a due date for completion and the unit's class may be suspended if the condition of class is not dealt with, or postponed by agreement, by the due date.

3.9.6 If it is found, from the reported condition of the hull or equipment or machinery or the drilling/process plant of a unit that an Owner has failed to comply with 1.4.6, 1.4.10, 1.3.4, 1.4.11, 3.4.1, 3.4.4 or 3.4.5, the class will be liable to be suspended or withdrawn, at the discretion of the Classification Committee, and a corresponding notation assigned. If it is considered that an Owner's failure to comply with these requirements is sufficiently serious, the suspension or withdrawal of class may be extended to include other units controlled by the same Owner, at the discretion of the Classification Committee.

3.9.7 If the Classification Committee is satisfied that a unit has been operated in a manner contrary to that agreed at the time of classification, or is being operated in environmental conditions which are more onerous than, or in areas other than, those agreed by the Classification Committee, the class will be withdrawn or suspended in relation to those operations.

3.9.8 If the Classification Committee is satisfied that a unit proceeded to sea with less freeboard than that approved by the Classification Committee, or that the freeboard marks are placed higher on the sides of the unit than the position assigned or approved by the Classification Committee, or, in cases where units do not have freeboards assigned, the draught is greater than that approved by the Classification Committee, the class of the unit will be withdrawn or suspended in relation to the above voyages.

3.9.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will be published by members of the LR Group. In cases where class has been suspended by the Classification Committee and it becomes apparent that the Owners are no longer interested in retaining LR's Class, it will be withdrawn.

3.9.10 For reclassification and reinstatement of class, *see* 3.3.2.

3.10 Appeal against Surveyor's recommendations

3.10.1 If the recommendations of the Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Classification Committee, who may direct a Special Examination to be held.

3.11 Ownership details

3.11.1 It is the responsibility of the Owner to inform a member of the LR Group in writing of any change to its contact details and, in the event of a unit sale, to supply details of the new Owners. If the new Owner of a unit cannot be properly identified nor contact details established, then the class of that unit will be specially considered by the Classification Committee. It is the responsibility of the new Owner to inform a member of the LR Group in writing of their contact details and that they are now responsible for the unit. If they fail to do so, the class of that unit will be specially considered by the Classification Committee.

3.12 Conversion surveys

3.12.1 The requirements in 3.1 are to be complied with.

3.12.2 A Special Survey as required for units of 20 years of age is to be completed at the time of conversion, *see* Pt 1, Ch 3,5.

3.12.3 All critical locations in the existing structure which may be prone to fatigue cracking are to be examined by MPI or other suitable NDE methods at the time of conversion, *see* Pt 10, Ch 1,6.3.

3.13 Life extension

3.13.1 The Classification Committee may permit a unit to remain in Class after the end of the design life of the unit, provided a life extension programme is completed satisfactorily.

3.13.2 The life extension programme is to be submitted to LR for approval.

Section 4
Third party audits and assessments

4.1 Audit of surveys

4.1.1 The surveys required by the Regulations may be subject to audit or assessment in accordance with the requirements of the relevant third party audit regimes, e.g., for mobile offshore units the requirements of the International Association of Classification Societies and the European Maritime Safety Agency.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,3.5. Except as amended at the discretion of the Classification Committee, the periods between such surveys are as follows:

(a) Annual Surveys, as required by Ch 2,3.5.1.
(b) Intermediate Surveys as required by Ch 2,3.5.2.
(c) Docking Surveys and In-water Surveys as required by Ch 2,3.5.3 and 3.5.4.
(d) Special Surveys at five-yearly intervals, *see* Ch 2,3.5.8, for alternative arrangements, *see also* Ch 2,3.5.10, 3.5.11 and 3.5.12.
(e) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,3.5.17.

1.1.2 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,3.5.11 and 3.5.19. The requirements of 1.1.1(a) to (c) are also to be complied with.

1.1.3 **Ship units and other surface type units:** for units with crude oil bulk storage tanks, the additional requirements of Pt 1, Ch 3, Sections 2, 3, 4, 5 and 7 of the Rules for Ships are to be complied with, as applicable.

1.1.4 For the frequency of surveys of boilers and other pressure vessels, steam pipes, screwshafts, tube shafts, propellers and thrusters, *see* Sections 10 to 12, *see also* 1.1.5.

1.1.5 For the frequency of surveys of pressure vessels for process and drilling plant, *see* Section 17.

1.1.6 For the frequency of surveys of process plant, drilling plant and riser systems, *see* Sections 13 to 15.

1.1.7 For the frequency of surveys of inert gas systems, *see* Section 18.

1.1.8 For the frequency of surveys of safety and communication systems and hazardous areas, *see* Section 16.

1.2 Surveys for damage or alterations

1.2.1 At any time when a unit is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g., if any part of the main or auxiliary machinery, including boilers, insulation or fittings, is removed for any reason, the steel structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed, the plating in way is to be examined before the cement or covering is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull, machinery, or drilling/process plant and the applicable statutory requirements, whether or not the appropriate statutory certificate has been issued by LR.

1.3.2 In the event of significant damage or defect affecting any unit, LR reserves the right to perform unscheduled surveys of the hull structure or machinery of other similar units classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention Certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member, when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed units, Convention Certificates may be issued by the other Society with which the unit is classed, provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 **Unit types** are defined in Ch 2,2 and Part 3.

1.5.2 **Critical areas** are locations vulnerable to substantial corrosion, buckling and/or fatigue cracking.

1.5.3 A **ballast tank** is a tank which is used solely for salt-water ballast. A space which is used for both the storage of liquids and salt-water ballast will be treated as a salt-water ballast tank when substantial corrosion has been found in that space.

1.5.4 **Spaces** are separate compartments such as tanks, pump-rooms, cofferdams and void spaces bounding cargo holds, decks and outer hull.

1.5.5 An **Overall Survey** is a survey intended to report on the overall condition of the hull structure and to determine the extent of additional Close-up Surveys as necessary.

1.5.6 A **Close-up Survey** is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e., normally within reach of hand.

1.5.7 **Representative spaces** are those which are expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces, account should be taken of the service and repair history on board and identifiable Critical Structural Areas.

1.5.8 **Substantial corrosion** is wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.9 A **protective coating** is normally a full hard protective coating. This is usually to be an epoxy coating or equivalent.

1.5.10 An **independent double bottom tank** is a double bottom tank which is separate from topside tanks, side tanks or deep tanks.

1.5.11 **NDE** is Non-Destructive Examination, consisting of visual examination and Non-Destructive Testing (NDT).

1.5.12 **Coating condition** is defined as follows:

GOOD Condition with only minor spot rusting.

FAIR Condition with local breakdown of coating at edges of stiffeners and weld connections and/or light rusting over 20 per cent or more of areas under consideration, but less than as defined for poor condition.

POOR Condition with general breakdown of coating over 20 per cent of areas and hard scale at 10 per cent or more of area under consideration.

1.5.13 A **prompt and thorough repair** is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, thereby removing the need for the imposition of any associated condition of class or recommendation.

1.5.14 **Critical structural areas** are locations which have been identified from calculations to require monitoring or from the service history of the subject unit or from similar units, if applicable, to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the unit.

1.6 Planned survey programme

1.6.1 A planned survey programme is to be developed by the Owner and submitted to LR for approval in advance of the first survey, *see* Ch 2,3.5.12. The programme should include guidance for control and recording of all relevant aspects of the inspection and replacement philosophy. In particular, the programme is to include and address the following:

(a) the overall design configuration;
(b) field life potential;
(c) appropriate regulatory requirements;
(d) main hull structural arrangement plans;
(e) details of planning, identification and preparation procedures;
(f) areas to be surveyed and extent of hull cleaning;
(g) inspection and testing schedules for all relevant compartments, equipment and systems;
(h) inspection methods and procedures;
(j) extent, frequency and circumstances for application of NDE;
(k) locations for non-destructive testing;
(l) schedule for overall survey, close-up survey and thickness measurement;
(m) condition of coatings and corrosion prevention systems;
(n) methods for reporting and recording of damage or deterioration found and remedial measures;
(o) allowable wastage limits (corrosion margins and wear allowances) for each part of the structure and mooring system.

1.6.2 Particular attention is to be paid to critical areas and also to areas of suspected damage or deterioration and to repaired areas. Surveys are to take into account locations highlighted by service experience and the design assessment.

1.6.3 A planned survey programme for positional mooring systems is to be developed by the Owner and submitted to LR for approval, *see* 2.2.11.

1.6.4 A planned survey programme for units assigned a **PPF** notation and/or a **DRILL** notation is to be developed by the Owner and submitted to LR for approval, *see* 2.5.5 and 2.7.1.

1.6.5 Planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

1.6.6 A planned survey programme for installations with riser systems assigned a **PRS** notation is to be developed by the Owner and submitted to LR for approval, *see* Section 15.

1.7 Preparation for survey and means of access

1.7.1 In order to enable the attending Surveyor(s) to carry out the survey, provision for proper and safe access is to be agreed between the Owner and LR. Tanks and spaces are to be safe for access, gas free and properly ventilated. Prior to entering a tank, void or enclosed space, it is to be verified that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

1.7.2 In preparation for survey, thickness measurements and to allow for a thorough examination, all spaces are to be cleaned, including removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc., to reveal corrosion, deformation, fractures, damages or other structural deterioration as well as the condition of the protective coating. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of renewed areas.

1.7.3 Sufficient illumination is to be provided to reveal corrosion, deformation, fractures, damages or other structural deterioration.

1.7.4 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way.

1.7.5 Survey at an offshore location or anchorage may be undertaken when the Surveyor is fully satisfied with the access, egress and communications arrangements provided and that the personnel on board are competent in the application and use of all relevant safety and communications equipment and procedures.

1.7.6 Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

1.8 Thickness measurement at survey

1.8.1 This Section is applicable to the thickness measurement of the structure where required by Sections 2, 3, 4 and 5.

1.8.2 Prior to the commencement of the Intermediate Survey and Special Survey, a meeting is to be held between the attending Surveyor(s), the Owner's representative in attendance, the thickness measurement company representative and the Master of the unit or an appropriately qualified representative appointed by the Master or Owner, so as to ensure the safe and efficient conduct of the survey and thickness measurements to be carried out. *See also* 1.6.1.

1.8.3 Thickness measurements are normally to be taken by means of ultrasonic test equipment and are to be carried out by a firm approved in accordance with LR's *Approval for Thickness Measurement of Hull Structure*.

1.8.4 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be re-coated as necessary.

1.8.5 Thickness measurements are to be taken in the forward and aft areas of all plates. Where plates cross ballast/cargo tank boundaries, separate measurements for the area of plating in way of each type of tank are to be reported. In all cases, the measurements are to represent the average of multiple measurements taken on each plate and/or stiffener. Where measured plates are renewed, the thickness of adjacent plates in the same strake is to be reported.

1.8.6 Thickness measurement of units with storage tanks for liquefied gases or chemicals will be specially considered.

1.8.7 The extent and frequency of thickness measurement on structure with substantial corrosion will be specially considered. The survey will not be considered complete until all required thickness measurements have been carried out.

1.8.8 Thickness measurements are to be witnessed by the Surveyor to the extent necessary to control the process. This also applies to thickness measurements carried out while the unit is at an offshore location.

1.8.9 Thickness measurements may be carried out within the 12 months prior to the due date of the Special Survey.

1.8.10 Where it is required as part of the survey to carry out thickness measurements for the structural areas subject to Close-up Survey, these measurements are to be carried out simultaneously with the Close-up Survey.

1.8.11 The Surveyor may extend the scope of thickness measurement if deemed necessary.

1.8.12 Thickness determination by drilling structural members is not permitted.

1.8.13 In all cases, the extent of the thickness measurements is to be sufficient to represent the actual average condition.

1.8.14 A report is to be prepared by the approved firm carrying out the thickness measurements. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the Operator.

1.8.15 The thickness measurement report is to be verified and signed by the Surveyor and countersigned by an authorising Surveyor.

1.9 Repairs

1.9.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the structural, watertight or weathertight integrity of the unit, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments and adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers and hatch coamings.

For locations where adequate repair facilities are not available, consideration may be given to allow the unit to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.9.2 Where it is proposed to defer repairs, a defect criticality assessment is to be submitted for approval, demonstrating the effectiveness of any mitigation measures (*inter alia* monitoring, loading restrictions) and continued suitability until repaired.

■ *Section 2* Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with statutory annual or other relevant statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the unit and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For ship units and other surface type units which are required by International Convention to comply with the International Safety Management Code (ISM Code), the Surveyor is to review the overall effectiveness of the Code on board the unit. This is to be undertaken regardless of the organisation issuing the Safety Management Certificate (SMC).

2.2 Structure and equipment

2.2.1 At each Annual Survey the exposed parts of the hull structure, deck, deck-houses, superstructures and structures attached to the deck, including supports to drilling/process plant, derrick substructures, crane pedestals and other supporting structures, accessible internal spaces and the applicable parts listed under unit types, as specified in 2.2.2 to 2.2.5, are to be generally examined and the Surveyor is to be satisfied as to their efficient condition.

2.2.2 **All unit types**. The Surveyor is to be satisfied regarding the efficient condition of:

- Hatchways, manholes and other openings in freeboard and superstructure decks or leading into buoyant spaces.
- Machinery casings and covers, companionways, and deck-houses protecting openings.
- Side scuttles and deadlights, and other openings in hull shell boundaries or in enclosed superstructures.
- Ventilators and air pipes together with flame screens, fiddley openings, skylights, flush deck scuttles and overboard discharges from enclosed spaces. In addition, the Surveyor is to examine externally all air pipe heads installed on exposed decks.
- Closing appliances for all the above, including check valves, hatch covers and doors, together with their respective securing devices, sills, coamings and supports.
- Watertight bulkheads, and end bulkheads of enclosed superstructures.
- Watertight doors and hatch covers in watertight boundaries, their indicators and alarms, to be examined and tested (locally and remotely), together with an examination of watertight boundary penetrations, so far as is practicable.
- Freeing ports together with bars, shutters and hinges.
- Windlasses and attachment of anchor racks and anchor cables.

- Protection of the crew, guard-rails, life-lines, gangways and deck-houses accommodating crew.
- The type, location and extent of corrosion control (i.e., coatings, cathodic protection systems, etc.), as well as its effectiveness, and repairs or renewals should be reported at each survey.

2.2.3 **Column-stabilised units and tension-leg units**. At the first Annual Survey subsequent to build, units are subject to examination of major structural components including NDE of critical areas, *see also* 1.6 and Ch 2,3.5.12. The Annual Survey is to include a complete bracing Close-up Survey, consisting of a detailed dry examination of all bracings and their structural connections to columns, pontoons and decks. The following critical regions are to be examined by approved methods of NDE:

(a) Primary bracing shell plating, including butts and seams and welding in way of the toes of both internal and external brackets (i.e., axial gusset or diaphragm plates and stiffener ends).
(b) Primary bracing shell plating and welding in way of changes of section, connections to main structure (e.g., columns, lower hulls, pontoons, decks, etc.) and intersections with other braces or node fabrications.
(c) All penetrations and attachments to primary bracings including drain, vent and access holes, hydrophone mountings, together with edge reinforcements, attachments for cathodic protection (both sacrificial anodes and impressed current systems), and guard-rail mountings, eye plates or lugs, etc.
(d) Diaphragm, bulkhead or deck plating and welding inside columns, pontoons or upper hull connection areas, in way of ends of primary bracings, local shear gussets between adjacent tube ends, and gussets, brackets of stiffeners forming a continuity of axial members from inside bracings. Also, column or deck plating and welded connections to bracings in way of internal diaphragm inside bracing.
(e) Column connections to lower hulls, pontoons and upper hull structure, including internal supporting structure.
(f) The structure in way of tether connections on tension-leg units.

It is important that an agreed procedure be established for the schedule of extent of examination and the proportion of NDE required at subsequent surveys, *see also* Ch 2,3.5.12. Specific critical regions are to be examined by approved methods of NDE. Column structure and upper hull structure where accessible above the waterline are to be generally examined.

2.2.4 **Self-elevating units**. At the first Annual Survey subsequent to build, units are subject to examination of major structural components, including NDE of critical areas, *see also* 1.6 and Ch 2,3.5.12. The Surveyor is to be satisfied regarding the efficient condition of:

- Jack-house structures and attachments to upper hull or platform.
- Locking system.
- Jacking or other elevating systems and leg guides, externally.
- Legs as accessible above the waterline.
- Plating and supporting structure in way of leg wells.
- Drilling derrick support structure.

It is important that an agreed procedure is established for the schedule of extent of examination and the proportion of NDE required at subsequent surveys, *see also* Ch 2,3.5.12. Specific critical regions to be examined by approved methods of NDE include the following:

(a) Leg guides and hull support structure.
(b) Leg well bulkheads below jacking tower or jack-house.
(c) Connections between jack-house structure and main deck and underdeck supporting structure.
(d) The jack-house roof above the jacking machinery (i.e., above the shock foundation) and in the vicinity of upper guide structure.
(e) General inspection of bracings, gussets, chord joints and racks of the legs. Inspection of tubular or similar type legs including pin holes.
(f) Leg connections to bottom mats or spud cans.
(g) Drilling derrick supporting structure.

2.2.5 **Ship units and other surface type units**. The requirements of Pt 1, Ch 3,2 of the Rules for Ships are to be complied with, as applicable. The Surveyor is to be satisfied regarding the efficient condition of:

- The hull and deck structure around the drilling wells and moonpools and in the vicinity of any other structural changes in section, slots, steps, or openings in the deck or hull and the back-up structure in way of structural members or sponsons connecting the hull.

2.2.6 The Surveyor is to confirm that an approved Operations Manual and Construction Portfolio are available on board, *see* Pt 3, Ch 1,3.

2.2.7 Where applicable, the following are to be examined where accessible:

- The hull and deck structure around turret openings and turret areas.
- Turret bearings and seals.
- Mooring arms and yokes.
- Mooring arm pivots and bearings.
- Process plant support stools and deck structure in way.
- Swivel stack support structure.
- Swivel stack bearing and seals.
- Mooring hawser line and mooring arm attachments to the hull structure.
- Mooring hawser to buoy.

2.2.8 The Surveyor is to confirm that, where required, an approved loading instrument, together with its operating instructions, is available on board, *see* Ch 2,1.4.8 and 1.4.9. The operation of the loading instrument is to be verified in accordance with LR's certification procedure.

2.2.9 For disconnectable units with equipment in accordance with Pt 4, Ch 9, anchors, cables, windlasses and winches are to be examined so far as practicable.

2.2.10 For units fitted with positional mooring equipment in accordance with Pt 3, Ch 10, an initial inspection is to be carried out following the installation of the positional mooring system, to ensure that the system has been properly installed, has not suffered damage and, through confirmation of agreed testing and maintenance procedures, that it continues to maintain the vessel in the defined safe envelope.

2.2.11 For positional mooring systems, a rota of component parts of the mooring system is to be examined at each Annual Survey. A periodic inspection program is to be developed by the Owners/Operators and submitted to LR for approval. Annual Surveys should be capable of determining as far as practicable the general condition of the mooring system, including cables, chains, fittings, fairleads, connections and equipment. The Surveyor is to be satisfied that all components and equipment remain in an acceptable condition. Particular attention is to be given to the following:

- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches and stoppers (including underwater stopper if fitted).
- Cable or chain in way of the splash zone.
- Cable or chain anchor line tension alarms are regularly tested at agreed intervals.
- Cable or chain tensions are regularly logged to confirm that agreed tensions have not been exceeded.

2.2.12 The Surveyor is to be satisfied regarding the freeboard marks on the unit's side.

2.2.13 The Surveyor is to be satisfied at each Annual Survey that no material alterations have been made to the unit, its structural arrangements, mooring system, subdivision, superstructure, fittings, and closing appliances upon which the stability approval and load line assignment is based.

2.2.14 The requirements of 3.2.3, 3.2.4, 5.3.5 and 5.3.6 regarding the survey of water ballast spaces are also to be complied with, as applicable.

2.2.15 The Surveyor is to carry out an examination and thickness measurement of areas identified at the previous Special Survey or Intermediate Survey as having substantial corrosion, *see* Section 5.

2.2.16 The Survey requirements for sea bed-stabilised units will be specially considered, but the requirements for column-stabilised and self-elevating units are to be complied with as applicable.

2.2.17 Survey requirements for units used for the storage of liquefied gas or chemicals will be specially considered.

2.2.18 Accessible areas on mooring buoys and mooring towers are to be generally examined.

2.3 Machinery

2.3.1 The main propulsion, essential auxiliary and emergency generators, including safety arrangements, controls and foundations, are to be generally examined. Surveyors are to confirm that Periodical Surveys of engines have been carried out as required by the Rules and that safety devices have been tested.

2.3.2 For units which are disconnectable in order to avoid hazards or extreme storm conditions, unless agreed otherwise with LR, the Surveyor is to examine and test in operation all main and auxiliary steering arrangements, including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements, where applicable. For laid-up machinery, *see* Section 20.

2.3.3 The Surveyor is to inspect generally the machinery and boiler spaces, with particular attention being given to the propulsion system, auxiliary machinery, and any potential fire and explosion hazards. Emergency escape routes are to be checked to ensure that they are free from obstruction.

2.3.4 The means of communication between the navigating bridge and the machinery control positions are to be tested.

2.3.5 The bilge pumping systems for each watertight compartment, including bilge wells, extended spindles, self-closing drain cocks, valves fitted with rod gearing or other remote operation, pumps and level alarms, where fitted, are to be examined and operated as far as practicable and all confirmed to be satisfactory. Any hand pumps provided are to be included.

2.3.6 Piping systems containing oil fuel, lubricating oil or other flammable liquids are to be generally examined and operated, as far as practicable, with particular attention being paid to tightness, fire precaution arrangements, flexible hoses and sounding arrangements.

2.3.7 The Surveyor is to be satisfied regarding the condition of non-metallic joints in piping systems which penetrate the hull, where both the penetration and the non-metallic joint are below the deepest load waterline.

2.3.8 Boilers and other pressure vessels and their appurtenances, including safety devices, foundations, controls, relieving gear, high pressure and waste steam piping insulation and gauges, are to be generally examined. Surveyors are to confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules and that the safety devices have been tested. Pressure vessels for process and drilling plant are to be examined in accordance with Section 17.

2.3.9 For boilers, the safety devices are to be tested and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the Log Book.

2.3.10 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.3.11 Gas and crude oil burning systems are to be generally examined and safety devices tested. Surveyors are to confirm that Periodical Surveys have been carried out as required by Section 10.

2.3.12 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions, so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled, they should be tested in the automatic mode.

2.3.13 Bonding straps for the control of static electricity and earthing arrangements are to be examined, where fitted.

2.3.14 For units having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.3.15 For units fitted with a dynamic positioning system and/or a thruster-assisted positional mooring system, the control system and associated machinery items are to be generally examined and tested under operating conditions to an approved Test Schedule.

2.3.16 For units fitted with automation equipment for main propulsion, essential auxiliary and emergency machinery, a general examination of the equipment and arrangements is to be carried out. Records of changes to the hardware and software used for controlling and monitoring systems for propelling and essential auxiliary machinery since the original issue (and their identification) are to be reviewed by the attending Surveyor. Satisfactory operation of the safety devices and controls systems is to be verified.

2.3.17 For units fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:
(a) Verification of evidence of satisfactory operation of the engine; where possible, this is to include a running test under load.
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems.
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.3.18 Dead unit starting arrangements for bringing machinery into operation without external aid are to be tested to the Surveyor's satisfaction.

2.3.19 Ballast control and indicating systems, along with audible and visual alarms, are to be examined and tested at both the main control station and each of the independent local control stations.

2.3.20 For self-elevating units, the jacking gear machinery and associated control system, including locking devices, are to be generally examined. A planned cycle is to be agreed with LR for the examination of critical components, i.e., pins, flexible hoses, couplings, gear reducers, etc., at each Annual Survey, supplemented where necessary by NDE, as agreed with LR.

2.3.21 Swivel stack including valves, manifolds and pipe connections are to be generally examined under working conditions, with special attention to damage due to mechanical handling, and all seals are to be checked for tightness. Suitable leakage tests may be carried out at the Surveyor's discretion and results of the grease sampling programme provided upon request.

2.3.22 On a single point mooring installation, automatic warning alarms of load monitoring systems are to be tested.

2.4 Safety and communication systems and hazardous areas

2.4.1 The Surveyor is to be satisfied as to the efficient condition as far as practicable of the following systems, in accordance with Part 7:
(a) Fire and gas alarm indication and control systems.
(b) Systems for broadcasting safety information.
(c) Protection system against gas ingress into safe areas.
(d) Protection system against gas escape in enclosed and semi-enclosed hazardous areas.
(e) Emergency shut-down (ESD) systems.
(f) Ventilation arrangements in hazardous areas around turret, swivel stack and mud processing areas are to be generally examined.
(g) Protection system against flooding including:
    (i) Water detection alarm systems for watertight bracings, columns, pontoons, footings, void watertight spaces and chain lockers.
    (ii) Bilge level detection and alarm systems on column- stabilised units and in machinery spaces on surface type units.
    (iii) Remote operation and indication of watertight doors and hatch covers and other closing appliances.
(h) Verification of the operation of manual and/or automatic doors.
(j) Protection of accommodation areas against the ingress of smoke.

2.4.2 For units where flammable mixtures are or may be present, a general examination of electrical equipment located in hazardous areas and spaces is to be made, to ensure that it is suitable for the application and that the integrity of safe type electrical equipment has not been impaired due to corrosion, missing bolts, etc. Cable runs should be examined so far as can be seen for sheath and armouring defects and to ensure that means of supporting the cable are in good order. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation, *see also* 2.2.2.

2.4.3 Satisfactory operation of automatic shut-down devices and alarms is to be verified.

2.4.4 Pressure vessels and safety devices are to be subject to surveys in accordance with the requirements of Sections 10 and 17.

2.5 Production and oil storage units

2.5.1 For units with crude oil bulk storage tanks, in addition to the applicable requirements of 2.1 to 2.4, the following are to be dealt with where applicable:

(a) Examination of oil storage tank openings including gaskets, covers, coamings and screens.
(b) Examination of oil storage tank pressure/vacuum valves and flame screens.
(c) Examination of flame screens on vents to all bunker, oily ballast and oily slop tanks and void spaces, so far as is practicable.
(d) Examination of crude oil storage washing, bunker, ballast and vent piping systems, together with flame arresters and pressure/vacuum valves, as applicable above the upper deck within the oil storage tank area, including vent masts and headers.
(e) Verification that no potential sources of ignition such as loose gear, excessive products in the bilges, excessive vapours, combustible materials, etc., are present in or near the oil storage pump-room and that access ladders are in good condition.
(f) Examination of all pump-room bulkheads for signs of leakage or fractures, and in particular, the sealing arrangements of all penetrations in these bulkheads.
(g) Verification that the pump-room ventilation system is operational, ducting intact, dampers operational and screens are clean.
(h) External examination of the piping and shut-off valves of oil storage tank and oil storage pump-room fixed fire-fighting system.
(j) Verification that the deck foam system and deck deluge system are in good operating condition.
(k) Examination of the condition of all piping systems in the oil storage pump-room so far as is practicable.
(l) Examination so far as is practicable of oil storage, ballast, bilges and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of pump-room bilge system, and checking that pump foundations are intact.
(m) Verification that installed pressure gauges on oil discharge lines and level indicator systems are operational.
(n) Verification that at least one portable instrument for measuring flammable vapour concentrations is available, together with a sufficient set of spares and a suitable means of calibration.
(o) Examination of any inert gas system, *see* 2.6.
(p) For units greater than 15 years of age, all ballast tanks adjacent (i.e., with a common plane boundary) to a cargo tank with any means of heating are to be examined. Thickness measurement is to be carried out where considered necessary by the Surveyor. Special consideration may be given by the Surveyor to those tanks or spaces where the coatings are found in GOOD condition, as defined in 1.5, at the previous Intermediate or Special Survey.
(q) For ballast tanks, in areas where substantial corrosion, as defined in 1.5, has been noted, additional measurements are to be carried out in accordance with Tables 3.7.7 to 3.7.15 in Pt 1, Ch 3 of the Rules for Ships, as applicable. The survey will not be considered complete until these additional thickness measurements have been carried out.

2.5.2 Safety and communication systems and hazardous areas are to be examined in accordance with 2.4.

2.5.3 For units where the requirements of Ch 2,1.4.11 are applicable, the arrangements for fire protection, detection and extinction are to be examined and are to include:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted.
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump, can be operated separately so that sufficient water can be produced to meet the greatest calculated demand in a credible emergency scenario.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharges containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnels, where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Examination of the electrical installation in areas which may contain flammable gas or vapour and/or combustible dust to verify that it is in good condition and has been properly maintained.

2.5.4 For units with production and process plant in which Pt 7, Ch 3 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the applicable requirements of 2.5.3. In addition, the passive fire protection systems to the topsides process modules and associated plant shall be examined to verify, so far as practicable, that no significant changes have been made to the arrangement of structural fire protection.

2.5.5 In addition to the applicable requirements of 2.1 to 2.4, for units with a process plant facility having a **PPF** notation, the Owner is to submit to LR a planned procedure for maintenance and inspection of the process plant facility for review and agreement by LR from the Survey aspects in advance of the first survey, *see* Ch 2,3.5.12. A copy is to be kept on board and made available to the Surveyor. The planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

2.5.6 The Surveyor is to be satisfied as far as is practicable as to the efficient condition of the following components to the process plant facility referred to in 2.5.5 as applicable, *see also* Pt 3, Ch 8:

- Major equipment and structures of the production and process plant.
- Oil or gas processing system.
- Production plant safety systems.
- Production plant utility systems.
- Relief and flare system.
- Well control system.
- Pressure vessels are to be subject to survey in accordance with the requirements of Section 17, *see also* 2.5.7.

2.5.7 Selected pressure safety valves are to be bench tested in accordance with a planned procedure for maintenance and inspection, *see* 2.5.5.

2.5.8 If the process plant facility is not classed but is certified by LR or another acceptable organisation, the survey and maintenance records of the process plant are to be made available to the Surveyor, who is to ensure that the records are up to date with no outstanding items which could affect the safety of the unit.

2.6 Inert gas systems

2.6.1 For inert gas systems, where fitted, the following are to be dealt with:

(a) External examination of the condition of piping, including vent piping, above the upper deck in the crude oil storage tank area and overboard discharges through the shell as far as practicable, together with components for signs of corrosion or gas leakage/effluent leakage.
(b) Verification of the proper operation of both inert gas blowers.
(c) Checking the scrubber room ventilation system.
(d) Checking, so far as is practicable, of the deck water seal for automatic filling and draining and checking for presence of water carry-over. Checking the operation of the non-return valve.
(e) Testing of all remotely operated or automatically controlled valves including the flue gas isolating valve(s).
(f) Checking the interlocking features of soot blowers.
(g) Checking the gas pressure regulating valve automatically closes when the inert gas blowers are secured.
(h) Checking, so far as is practicable, the following alarms and safety devices of the inert gas system, using simulated conditions where necessary:
   (i) High oxygen content of gas in the inert gas main.
   (ii) Low gas pressure in the inert gas main.
   (iii) Low pressure in the supply to the deck water seal.
   (iv) High temperature of gas in the inert gas main.
   (v) Low water pressure to the scrubber.
   (vi) Accuracy of portable and fixed oxygen measuring equipment by means of calibration gas.
(j) Checking of the interlocking features and positive isolation for tank isolation.

2.7 Drilling units

2.7.1 In addition to the applicable requirements of 2.1 to 2.4, for units having a **DRILL** notation, the Owner is to submit to LR a planned procedure for maintenance and inspection of the drilling plant facility for review and agreement by LR from the survey aspect in advance of the first survey, *see* Ch 2,3.5.12. A copy is to be kept on board and made available to the Surveyor. The planned surveys and procedures as agreed by LR will be subject to revision if found necessary at subsequent surveys or when required by the Surveyor.

2.7.2 The Surveyor is to be satisfied as far as is practicable as to the efficient condition of the following components of the drilling plant facility referred to in 2.7.1, as applicable, *see also* Pt 3, Ch 7:

- Blow out preventer hoisting and handling equipment.
- Blow out preventer, diverter and their control systems.
- Choke manifold and associated valves.
- Bulk storage.
- Drilling fluids circulation and cementing equipment.
- Drilling derrick and hoisting, rotation and pipe handling equipment.
- Heave compensation equipment.
- Miscellaneous drilling equipment and equipment considered as part of the drilling installation.
- Well testing equipment.
- Well protection valve and control systems.

2.7.3 Safety and communication systems and hazardous areas are to be examined in accordance with 2.4.

2.7.4 Pressure vessels forming part of the drilling plant facility are to be subject to surveys in accordance with the requirements of Section 17, *see also* 2.7.5.

2.7.5 Selected pressure safety valves are to be bench tested in accordance with a planned procedure for maintenance and inspection, *see* 2.7.1.

2.7.6 If a drilling plant facility is not classed but is certified by LR or another acceptable organisation, the survey and maintenance records of the drilling plant are to be made available to the Surveyor, who is to ensure that the records are up to date with no outstanding items which could affect the safety of the unit.

Section 3 **Intermediate Surveys – Hull and machinery requirements**

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of Section 2 are to be complied with, so far as applicable.

3.2.2 A general examination of salt-water ballast spaces is to be carried out by the Surveyor as required by 3.2.5 and 3.2.6. If such examinations reveal no visible structural defects, the examination may be limited to a verification that the protective coating remains in GOOD or FAIR condition, as defined in 1.5. When considered necessary by the Surveyor, thickness measurement of the structure is to be carried out.

3.2.3 For salt-water ballast tanks, other than independent double bottom tanks, where a protective coating is found to be in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

3.2.4 For independent salt-water double bottom tanks where a protective coating is found to be in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class may, at the discretion of the Classification Committee, be subject to the spaces in question being examined and gauged as necessary at Annual Surveys.

3.2.5 For all units over five years of age and up to 10 years of age, representative salt-water ballast tanks and other spaces are to be examined as follows:

- **Column-stabilised units and tension-leg units**
  Representative ballast tanks in pontoons, lower hulls, and free-flooding compartments as accessible, and at least two ballast tanks in columns and upper hull, if applicable.
- **Self-elevating units**
  Representative ballast tanks and at least two representative pre-load tanks. Accessible free-flooding compartments in mat or footings.
- **Ship units and other surface type units**
  One peak tank and at least two other representative ballast tanks between the peak bulkheads used primarily for water ballast.
- **Deep draught caissons**
  Representative ballast tanks where accessible.
- **All unit types**
  Particular attention is to be given to corrosion control systems in ballast tanks, free-flooding areas and other locations subjected to sea-water from both sides where accessible.

For tanks other than independent double bottom tanks, where a protective coating is found in POOR condition, as defined in 1.5, or other defects are found, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type. For independent double bottom tanks where substantial corrosion or other defects are found, the examination is to be extended to other ballast tanks of the same type.

3.2.6 For all unit types over 10 years of age, the following is required:

(a) All salt-water ballast tanks and free-flooding areas are to be examined.
(b) The anchors on units assigned the character **(1)** are to be partially lowered and raised using the windlass.

3.2.7 The Surveyor is to carry out an examination and thickness measurement of structure identified at the previous Special Survey as having substantial corrosion, *see* Section 5.

3.2.8 In addition to 3.2.1 to 3.2.7 on units with crude oil bulk storage tanks, the following are to be dealt with where applicable:

(a) An examination of oil storage, crude oil washing, bunker, ballast, steam and vent piping on weather decks, as well as vent masts and headers. If, upon examination, there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, gauged, or both.
(b) A general examination within the areas deemed as dangerous, such as cargo pump-rooms and spaces adjacent to and zones above cargo tanks, for defective and non-certified safe type electrical equipment, improperly installed, defective and dead-end wiring. An electrical insulation resistance test of the circuits terminating in, or passing through, the dangerous areas is to be carried out. If the unit is not in a gas-free condition, the results of previously recorded test readings may be accepted.

3.2.9 For all units, the electrical generating sets are to be examined under working conditions to verify compliance with Pt 6, Ch 2,2.2.

3.2.10 The following are to be examined where accessible:

- Turret and circumturret structure.
- Turret bearings and seals.
- Swivel stack bearings and seals.
- Mooring arm pivots and bearings.

3.2.11 For units with crude oil bulk storage tanks, in addition to 3.2.6, the following is required for units over 10 years and less than 15 years of age:

(a) Overall survey of all salt-water ballast tanks, including any combined salt-water ballast/crude oil storage tanks.
(b) Overall survey of at least two representative crude oil storage tanks.

(c) Close-up Survey of salt-water ballast tanks to the same extent as the previous Special Survey and two combined cargo/ballast tanks. Where protective coatings are found to be in GOOD condition, as defined in 1.5, the extent of Close-up Survey may be specially considered.
(d) The thickness measurement requirements of 3.2.7 are to be complied with. In areas where substantial corrosion, as defined in 1.5, has been noted, additional measurements are to be carried out to the satisfaction of the Surveyor. The survey will not be considered complete until these additional thickness measurements have been carried out.
(e) Machinery and boiler spaces, including tank tops, bilges and cofferdams, sea suctions and overboard discharges, are to be generally examined.

3.2.12 For units with crude oil bulk storage tanks, in addition to 3.2.8 and 3.2.11, the following is required for units over 15 years of age:
(a) A survey to the same extent as the previous Special Survey (applicable only to ESP surveys, *see* Pt 1, Ch 3,7.1.2 of the Rules for Ships).
(b) Pressure testing of cargo and ballast tanks is to be carried out if deemed necessary by the attending Surveyor.

■ *Section 4* Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys in lieu of Docking Surveys, the Surveyor is to examine the unit and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition, *see also* Ch 2,3.5.3.

4.2 Docking Surveys

4.2.1 Where a unit is in dry dock or on a slipway, it is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary, for the examination of the shell, including bottom and bow plating, keel, sponsons and appendages, stern, sternframe and rudder. The rudder is to be lifted for examination of the pintles if considered necessary by the Surveyor.

4.2.2 For self-elevating units, the leg footings and those parts of the leg and hull that are normally under water are to be examined. The connections between leg chords and the footings or mats are to be inspected and subjected to NDE.

4.2.3 For self-elevating units, at each Docking Survey or equivalent coinciding with Special Survey, the Surveyor is to be satisfied with the internal condition of the leg footings or mats.

4.2.4 For column-stabilised units, external surfaces of the upper hull or platform, footings, pontoons or lower hulls, underwater areas of columns, bracing and their connections, sea chests, and propulsion units as applicable, are to be selectively cleaned and examined to the satisfaction of the attending Surveyor. Non-destructive testing may be required of areas considered to be critical or found to be suspect by the Surveyor.

4.2.5 The shell plating is to be examined for excessive corrosion, deterioration due to chafing or contact with the ground and for undue unfairness or buckling. Special attention is to be given to the connections between the bilge strakes and bilge keels.

4.2.6 The external cathodic protection system and coatings are to be examined.

4.2.7 The clearances in the rudder bearings are to be measured. Where applicable, pressure testing of the rudder may be required if deemed necessary by the Surveyor.

4.2.8 The sea connections and overboard discharge valves and cocks and their attachments to the hull are to be examined.

4.2.9 Thrusters, propeller, sternbush and sea connection fastenings and the gratings at the sea inlets are to be examined.

4.2.10 The clearance in the sternbush or the efficiency of the oil glands is to be ascertained.

4.2.11 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.30. For units having a positional mooring notation in accordance with Pt 3, Ch 10, the positional mooring systems and associated equipment are also to be examined.

4.2.12 For electrical equipment survey requirements of units five years old and over, *see* 9.3.

4.3 In-water Surveys

4.3.1 When it is not practicable to dry-dock a unit or when an Owner does not intend to dry-dock a unit during its normal service life, the Classification Committee will accept an In-water Survey in lieu of docking on units where an **OIWS** notation is assigned, *see* Ch 2,2.4.13.

4.3.2 Special arrangements must be incorporated into the unit's design or otherwise provided to allow adequate survey of thrusters, stern bearings, rudder bearings, sea suctions and valves, etc., *see* Pt 3, Ch 1,2.1.3.

4.3.3 Special consideration shall be given to ascertaining rudder bearing clearances and sternbush clearances, based on a review of the operating history, onboard testing and stern bearing oil analysis. These considerations are to be included in the proposals, *see* 4.3.5.

4.3.4 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as practicable.

4.3.5 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.6 A planned procedure for the routine inspection of the underwater areas is to be agreed between the Owners and LR. A procedure document is to be placed on board the unit and made available to the Surveyor. Where survey experience indicates that modifications are required to the inspection procedures, the procedure document is to be modified to the satisfaction of LR.

4.3.7 The In-water Survey is to be carried out at an agreed geographical location, with the Surveyor to LR satisfied that the unit at a suitable draught and the conditions satisfactory for diver or ROV inspection. The in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver/ROV operator.

4.3.8 In general, the In-water Survey is to be carried out by an approved diving company with suitably qualified divers. Alternatively, the In-water Survey may be carried out using a suitable ROV, subject to agreement with the attending LR Surveyor. The ROV should be fitted with suitable cameras, transmission and recording facilities.

4.3.9 The efficient condition of the cathodic protection system and the high resistance paint is to be confirmed at each In-water Survey to the satisfaction of the Surveyors, in order that the **OIWS** notation can be maintained.

4.3.10 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the unit be dry-docked, in order that a more detailed survey can be undertaken and the necessary work carried out.

4.3.11 Diver/ROV-assisted surveys are not acceptable for the periodic survey inspections of primary bracing members, or intersections of bracings with columns or pontoons, or column to pontoon intersections on column-stabilised units, except in exceptional circumstances when specially agreed with the Classification Committee and the procedures have been approved, *see also* 2.2.3.

4.3.12 Turret and bearings below water level, underwater parts of mooring towers and/or articulated towers (where applicable), chain stoppers, chain cables and mooring lines/chains are to be examined as far as practicable during In-water Surveys. On tension-leg units, tethers and their upper and lower connections are to be examined.

4.3.13 For electrical equipment survey requirements of units five years old and over, *see* 9.3.

4.3.14 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.13.

4.3.15 For self-elevating units, the requirements of 4.2.2 and 4.2.3 are to be undertaken as far as practicable with due consideration to the operation and location of the unit.

■ *Section 5* **Special Survey – Hull requirements**

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull/structure and related piping is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to periodical surveys being carried out as required by the Regulations.

5.1.2 The examination is to be sufficient to ascertain substantial corrosion, significant deformation, fractures, damages or other structural deterioration and, if deemed necessary by the Surveyor, suitable non-destructive examination may be required.

5.1.3 The requirements of 1.6 are to be complied with as applicable for all units.

5.1.4 The requirements of Section 2 are to be complied with, as applicable, for all units.

5.1.5 A Docking Survey, or an In-water Survey in lieu of a Docking Survey, in accordance with the requirements of Section 4 is to be carried out as part of the Special Survey.

5.1.6 During the Docking Survey, or an In-water Survey in lieu of a Docking Survey, for installations with crude oil bulk storage tanks, the overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo spaces and ballast tanks are to be carried out as required, if not already surveyed.

5.1.7 **Ship units and other surface type units**. For units with crude oil bulk storage tanks, the requirements of Pt 1, Ch 3,7 of the Rules for Ships are to be complied with as applicable. For units with liquefied gas cargo containment systems, the additional requirements of Pt 1, Ch 3,9 of the Rules for Ships are to be complied with as applicable.

5.2 Preparation

5.2.1 The unit is to be prepared as necessary for the Surveyors to gain proper access for the careful inspection and examination of all items listed in this Section. Voids and closed spaces are to be thoroughly ventilated to ensure adequate levels of oxygen in the air, fuel tanks, oil storage tanks and other similar spaces are to be gas freed and cleaned as necessary and paint lining, insulation and other coatings and coverings are to be removed locally if required by the Surveyors.

5.2.2 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided that it is inspected, tested by beating and chipping and found sound and adhering satisfactorily to the steel.

5.2.3 **Ship units and other surface type units**. The requirements of Pt 1, Ch 3,5.2 of the Rules for Ships are to be complied with, as applicable.

5.3 Examination and testing

5.3.1 All spaces within the hull/structure and superstructure are to be subject to an overall survey and examination.

5.3.2 Watertight integrity of tanks, bulkheads, hull, decks and other compartments is to be verified by visual inspection.

5.3.3 **Ship units and other surface type units**. The requirements of Pt 1, Ch 3,5.3 of the Rules for Ships are to be complied with, as applicable. Testing of crude oil storage tanks is to be carried out as deemed necessary by the attending Surveyor. For units assigned an **ESP** notation, the requirements of Pt 1, Ch 3,7.5 of the Rules for Ships are to be complied with as applicable, *see also* 5.3.15.

5.3.4 For tank internal examinations, the requirements of Pt 1, Ch 3,5.3.2 of the Rules for Ships are to be complied with as applicable.

5.3.5 In spaces used for salt-water ballast, excluding double bottom tanks, where a protective coating is found in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class will be subject to the space in question being internally examined and gauged as necessary at Annual Surveys.

5.3.6 For independent salt-water double bottom tanks where a protective coating is found to be in POOR condition, as defined in 1.5, and it has not been repaired, where a soft or semi-hard coating has been applied or where a protective coating was not applied from the time of construction, maintenance of class may, at the discretion of the Classification Committee, be subject to the spaces in question being examined and gauged as necessary at Annual Surveys.

5.3.7 Double bottom, deep, ballast, peak and other tanks, including cargo holds assigned also for the carriage of salt-water ballast, are to be tested with a head of liquid to the top of air pipes or to the top of hatches for ballast/cargo holds. Boundaries of oil fuel, lubricating oil and fresh water tanks are to be tested with a head of liquid to the maximum filling level of the tank. Tank testing of oil fuel, lubricating oil and fresh water tanks may be specially considered, based upon a satisfactory external examination of the tank boundaries, and a confirmation from the Master stating that the pressure testing has been carried out according to the requirements with satisfactory results.

5.3.8 Where repairs are effected to the shell plating or bulkheads, any tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.9 In units with crude oil storage tanks, all piping systems on deck and within the storage tanks and adjacent spaces are to be examined to ensure that tightness and condition remain satisfactory. Special attention is to be given to ballast piping in storage tanks and crude oil storage piping in ballast tanks, pump-rooms, pipe tunnels and void spaces.

5.3.10 Where substantial corrosion, as defined in 1.5, is identified in crude oil storage tanks and is not rectified, this will be subject to re-examination at Annual and Intermediate Surveys and is to be gauged as necessary.

5.3.11 At the first Special Survey and at subsequent Special Surveys, representative tanks are to be examined by a Close-up Survey. The extent of the survey is to be agreed with LR in advance of the survey. For all units over 10 years of age, all salt-water ballast tanks and free-flooding areas where accessible are to be examined.

5.3.12 The attachment to the structure and condition of anodes in all tanks is to be examined.

5.3.13 In addition to the requirements of 5.3.1, column-stabilised units and tension-leg units are to have a complete bracing Close-up Survey consisting of a detailed dry examination of all bracings and their structural connections to columns and decks. The connections of columns to lower hulls, pontoons and upper hulls are to be examined. All critical regions defined in 2.2.3 are to be examined by approved methods of NDE, *see also* Ch 2,3.5.12. Primary structure of the upper hull or platform which form 'Box' or 'I' type supporting structure and their end connections are to be examined. All free-flooding areas and sponsons are to be examined.

5.3.14 In addition to the requirements of 5.3.1, self-elevating units are to have a complete survey of all legs, footings and mats. Particular attention is to be given to the leg structure in way of the waterline. Tubular or similar type legs are to be examined externally and internally, including stiffeners and pin holes. All critical regions defined in 2.2.4 are to be examined by approved methods of NDE, including the leg connections to footings or mats, *see also* Ch 2,3.5.12. Jetting piping systems or other external piping, particularly where penetrating footings or mats, are to be examined.

5.3.15 In addition to the requirements of 5.3.1, surface type units are to have a Close-up Survey carried out in accordance with an agreed programme, *see also* 1.6.1. The programme should identify all critical areas of primary structure components and connections within compartments to be surveyed. Special attention is to be given to underdeck structure supporting topside equipment, flare stack and cranes, etc. The Surveyor may extend the Close-up Survey if deemed necessary, taking into account the maintenance of the tanks under survey and the condition of the corrosion prevention system. For areas in tanks where coatings are found to be in GOOD condition, as defined in 1.5.12, the extent of Close-up Survey may be specially considered.

5.3.16 In addition to the requirements of 5.3.1, structural appendages and ducts for positioning units, sponsons and positioning spuds on surface type units are to be examined.

5.3.17 On all units, careful examination is to be made of those parts of the structure particularly liable to excessive corrosion, or to deterioration or damage from causes such as chafing, lying on the sea bed or handling of drilling equipment, stores, etc., and due to water collection in corners of bulkheads and on weather decks, and in other exposed areas.

5.3.18 All decks including helidecks and their supporting structure, deck-houses, casings and superstructures are to be examined. Where aluminium alloy is used in the structure, bimetallic joints are to be examined as far as practicable. Lifeboat and winch platforms and their supporting structures are to be examined.

5.3.19 Wood decks and sheathing are to be examined. If decay or rot is found or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

5.3.20 Primary bulkheads in the upper hull of column-stabilised units and in the hull of self-elevating units are to be examined. Particular attention is to be given to the structure below and derrick sub-structures and supports under process plant, drilling derricks and other heavy equipment. Bulkheads adjacent to leg wells, turrets and moonpools are to be examined. Bulkhead penetrations in way of doors and other openings are to be examined.

5.3.21 A Close-up Survey of structure around external and internal turrets is to be held as per an agreed planned survey programme. Thickness measurements are to be made as per the agreed planned survey programme, *see* Pt 1, Ch 2,3.5.12. Turret bearings are to be examined in accordance with the manufacturers' recommendations and agreed survey programme. Records of analyses of turret and swivel bearing seals and lubricants are to be examined by the Surveyors for compliance to manufacturers' standards and/or recommendations.

5.3.22 Mooring buoys, mooring arms and yokes, mooring towers, and other similar special features of the installation are to be specially examined in accordance with an agreed planned survey programme.

5.3.23 For deep draught caisson units having combined oil/ballast tanks which for operational requirements are always full, the periodic survey programme is to be agreed to at the design stage. Owners may consider installing suitable steel coupon plates in these tanks, where practicable, to monitor corrosion. Where coupon plates are fitted, their position will be specially considered and they are to be electrically insulated from the unit. Weight and thickness of the coupon plates are to be recorded and reported at each special survey.

5.3.24 For tension-leg units, a Close-up Survey of the structure in way of tethers is to be carried out.

5.3.25 For units having a **DRILL** notation, the drilling derrick, including bolting arrangements is to be examined. Other structural components and supports forming part of the drilling plant are to be examined and tested as necessary, *see also* 2.7.

5.3.26 For production units with a process plant facility having a **PPF** notation, all plant supporting structure, including bracing trusses and skids, is to be examined, *see also* 2.5.6.

5.3.27 The requirements for thickness determination of the structure of all unit types are to be in accordance with 5.4.

5.3.28 Crane pedestals and similar supporting structures to access gangways and flare booms, masts and standing rigging are to be examined.

5.3.29 At the second Special Survey and subsequent Special Surveys, chain lockers are to be cleaned and examined internally.

5.3.30 For disconnectable units and mobile offshore units assigned the character figure **(1)**, anchors are to be examined. Anchors are to be partially lowered and raised by the windlass or winch as applicable. The chain cables and wire rope cables are to be examined as far as practicable. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The anchor windlass or winch is to be examined. For equipment forming part of a positional mooring system, *see* 5.5.

5.3.31 The hand pumps, suctions, watertight doors, air and sounding pipes are to be examined. In addition, the Surveyor is to examine internally air pipe heads in accordance with the requirements of Table 3.5.1.

5.3.32 The Surveyor is to be satisfied as to the efficient condition of the helm indicator, protection of aft steering wheel and gear on self-propelled units.

5.3.33 Foundations and supporting headers, brackets and stiffeners for drilling-related apparatus, where attached to hull, deck, substructure or deck-house, are to be examined.

5.3.34 Foundations of machinery are to be examined.

5.4 Thickness measurement

5.4.1 The requirements for thickness measurements given in 1.8 are to be complied with.

5.4.2 In addition to the thickness measurements required by 5.4.1 to ascertain local wastage, thickness measurement is to be carried out on units with crude oil bulk storage tanks at the first Special Survey and at subsequent Special

Table 3.5.1 Air pipe head internal examination requirements (applicable for automatic air pipe heads installed on exposed decks of all units)

Special Survey I (Units 5 years old)	Special Survey II (Units 10 years old)	Special Survey III (Units 15 years old) and subsequent
(1) Two air pipe heads (one port and one starboard) on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5 (2) Two air pipe heads (one port and one starboard) on the exposed decks, serving spaces aft of 0,25*L* *See* Notes 1 to 5	(1) All air pipe heads on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5 (2) At least 20% of air pipe heads on exposed decks, serving spaces aft of 0,25*L*. *See* Notes 1 to 5	All air pipe heads on exposed decks. *See* Notes 1 to 6

NOTES
1. Air pipe heads serving ballast tanks are to be selected where available.
2. The Surveyor is to select which air pipe heads are to be examined.
3. Where considered necessary by the Surveyor as a result of the examinations, the extent of examinations may be extended to include other air pipe heads on exposed decks.
4. Where the inner parts of an air pipe head cannot be properly examined due to its design, it is to be removed in order to allow an internal examination.
5. Particular attention is to be given to the condition of the zinc coating in heads constructed from galvanised steel.
6. Exemption may be considered for air pipe heads where there is documented evidence of their replacement within the previous five years.

Surveys, in accordance with the requirements of Pt 1, Ch 3,5.6 and Pt 1, Ch 3,7.7 of the Rules for Ships, as applicable.

5.4.3 On all other unit types, thickness measurement is required at the second Special Survey and at subsequent Special Surveys. Thickness measurement of the primary hull structure is to include the shell plating of hulls, pontoons, columns, bracings, main strength decks, bulkheads, legs, footings, mats and the structure of representative salt-water ballast and pre-load tanks and other tanks and critical areas as required by the Surveyor, to determine the amount of any general diminution in thickness. The extent and location of such measurements are to be agreed by LR prior to each survey, *see also* 1.6.1.

5.4.4 A report is to be prepared by the qualified firm carrying out the thickness measurements. The report is to give the location of measurement and the thickness measured as well as the corresponding original thickness. The report is to give the date when measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the Operator.

5.4.5 The thickness measurement report is to be verified and signed by the Surveyor and countersigned by an Authorising Surveyor.

5.5 Positional mooring systems

5.5.1 On units fitted with positional mooring equipment which have been assigned a special features notation in accordance with Pt 3, Ch 10, the requirements for annual surveys in 2.2.11 are to be complied with.

5.5.2 Where practicable, mooring cables, chains and anchors are to be lifted to the surface for detailed inspection in accordance with 5.5.3 and 5.5.4 at each Special Survey. Alternatively, *in situ* inspection, using acceptable techniques, will be considered by LR when requested. *See also* Pt 3, Appendix B for guidance notes on the inspection of positional mooring systems.

5.5.3 As far as practicable, the Surveyor is to determine the general condition of the mooring system, including cables, chains, fibre ropes, fittings, fairleads, connections and equipment. Particular attention is to be given to the following:

- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches and stoppers.
- Cable or chain in way of the splash zone.
- Cable or chain in the contact zone of the sea bed.
- Damage to mooring system.
- Extent of marine growth.
- Condition and performance of corrosion protection.

5.5.4 Anchors of mobile offshore units are to be cleaned and examined. Wire rope anchor cables are to be examined. If cables are found to contain broken, badly corroded or bird caging wires, they are to be renewed. Chain cables are to be ranged and examined. Maximum acceptable diminution of anchor chain in service will normally be limited to a two per cent reduction from basic chain diameter (basic chain diameter can be taken as the diameter, excluding any design corrosion allowance, which satisfies the Rule requirement for minimum factors of safety).

5.5.5 The windlasses or winches are to be examined.

5.5.6 Structure in way of anchor racks and anchor cable fairleads is to be examined.

Section 6 Machinery Surveys – General requirements

6.1 Annual, Intermediate, Docking and In-water Surveys

6.1.1 For Annual, Intermediate, Docking and In-water Surveys, *see* Sections 2, 3 and 4.

6.1.2 For laid-up machinery, *see* Section 20.

6.2 Complete Surveys

6.2.1 While the unit is in dry dock or subject to In-water Surveys, all openings to the sea in the machinery spaces, pump-rooms and other spaces, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined and the fastenings to the shell plating are to be renewed when considered necessary by the Surveyor.

6.2.2 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 12), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.3 An examination is to be made of all reduction gears, complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.4 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and mooring winches and associated driving equipment, where fitted.
(d) Evaporators (other than those of vacuum type) and their safety valves, which should be seen in operation under steam.
(e) The holding-down bolts and chocks of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

6.2.5 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.6 The valves, cocks and strainers of the bilge system, including bilge injection, are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems, also the ballast connections and blanking arrangements to deep tanks, pre-load tanks or brine tanks which may carry different liquid, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.7 Fuel tanks which do not form part of the unit's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

6.2.8 Arrangements are to be made by Owners for opening up and examination of all sea connections afloat at five-yearly intervals.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to under operating conditions to an approved test scheule.

6.2.10 On units fitted with a dynamic positioning system and/or thruster-assisted positional mooring system, the control system and associated machinery items, including pressure vessels, are to be examined and tested to demonstrate that they are in good working order.

6.2.11 In addition to the above, detailed requirements for steam and gas turbines, oil engines, electrical installations and boilers are given in Sections 7, 8, 9 and 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Classification Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g., vibration indicators) and operational records.

6.2.12 For self-elevating units, the following essential parts of the elevating and lowering machinery, which are critical to the safety of the unit, are to be specially examined:

(a) Couplings, pinions and gears of the climbing pinion gear train of rack and pinion systems are to be examined and NDE is to be carried out to the Surveyor's satisfaction.
(b) Attachment of the reduction gear case to the jackcases or other supporting structure is to be examined for wear and bolting arrangements examined for security.
(c) Leg guides and shock pads are to be examined for wear.
(d) The fixation system, where fitted, is to be examined for wear and satisfactory operation/engagement.
(e) Grease injection lubrication system is to be examined for damage to piping and nozzles. Satisfactory operation of system is to be verified.
(f) Operational tests of the jacking system are to be carried out to the Surveyor's satisfaction.

6.2.13 Where an approved planned maintenance scheme is in operation, surveys may be carried out in accordance with Ch 2,3.5.21 and 3.5.22.

■ *Section 7* Turbines – Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of Section 6 are to be complied with.

7.1.2 The working parts of the main engines and attached pumps, and of auxiliary machinery used for essential services, are to be opened out and examined, including:

- For turbine machinery:
  Bulkhead stop valves and manoeuvring valves.
  Blading and rotors.
  Flexible couplings.
  Casings.

7.1.3 In gas turbines and free piston gas generators, the following parts are also to be opened out and examined:

- Impellers or blading.
- Rotors and casings of the air compressors.
- Combustion chambers and burners.
- Intercoolers and heat exchangers.
- Gas and air piping, and fittings.
- Starting and reversing arrangements.

7.1.4 Where gas turbines operate in conjunction with free piston gas generators, the following parts of the latter are to be opened out and examined:

- Gas and air compressor cylinders and pistons.
- Compressor end covers.
- Valves and valve gear.
- Fuel pumps and fittings.
- Synchronising and control gear.
- Cooling system.
- Explosion relief devices.
- Gas and air piping.
- Receivers and valves, including bypass arrangements.

7.1.5 Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers, and any other appliances used for essential services, are to be examined to the satisfaction of the Surveyor, and if it is considered necessary, they are to be tested.

7.1.6 The manoeuvring of the engines is to be tested under working conditions.

7.1.7 Exhaust steam turbines supplying power for main propulsion purposes, together with their gearing and appliances, steam compressors or electrical machinery, are to be examined, so far as is practicable. Where cone connections to internal gear shafts are fitted, the coned ends are to be examined, so far as is practicable.

7.1.8 In units having essential auxiliary machinery driven by oil engines, the prime movers of these auxiliaries are to be examined as detailed in Section 8.

■ *Section 8* Oil engines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 6 are to be complied with.

8.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Pistons, piston rods, connecting rods, crossheads and guides.
- Valves and valve gear.
- Crankshafts and all bearings.
- Crankcases, bedplates and entablatures.
- Crankcase door fastenings, explosion relief devices and scavenge relief devices.
- Scavenge pumps, scavenge blowers, superchargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.1.3 Selected pipes in the starting air system are to be removed for internal examination and thickness measurement is to be carried out where considered necessary by the Surveyor. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.1.4 The electric ignition system, if fitted, is to be examined and tested.

8.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

8.1.6 Where steam is used for essential purposes, the condensing plant, feed pumps and oil fuel burning plant are to be examined and the steam pipes examined and tested as detailed in Section 11.

■ *Section 9* Electrical equipment

9.1 Annual and Intermediate Surveys

9.1.1 The requirements of Sections 2 and 3 are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be subdivided, or equipment which may be damaged disconnected, for the purpose of this test.

9.2.2 The fittings on the main and emergency switchboard, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices, including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 Air circuit-breakers for essential or emergency services and rated at 800A and above are to be surveyed to ensure that the manufacturer’s recommended number of switching options has not been exceeded. *See* Pt 6, Ch 2,7.3.6 of the Rules for Ships. Where a breaker is not fitted with an automatic counter, a written record is to be kept.

9.2.5 The electric cables are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 9.2.1.

9.2.6 The generator prime movers are to be surveyed as required by Sections 7 and 8 and the governing of the engines tested. The motors concerned with essential services, together with associated control and switch gear, are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.7 Where transformers associated with supplies to essential services are liquid immersed, the Owner is to arrange for samples of the liquid to be taken and tested for dissolved gases, breakdown voltage, acidity and moisture by a competent testing authority, in accordance with the equipment manufacturer’s requirements, and a certificate giving the test results is to be made available to the Surveyor on request.

9.2.8 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.9 The emergency sources of electrical power, their automatic arrangements and associated circuits are to be tested.

9.2.10 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as is practicable.

9.2.11 Where the unit is electrically propelled, the propulsion motors, generators, propulsion transformers, propulsion conversion equipment, cables, harmonic filters, neutral earthing resistors, dynamic breaking resistors and all ancillary electrical equipment that forms part of the propulsion drive and control system, exciters and ventilating plant (including coolers) associated therewith are to be surveyed and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. Where practicable, the low voltage and high voltage windings of resin coated propulsion transformers are to be subjected to boroscopic inspection, to assess the physical condition of their insulation and for signs of mechanical and thermal damage. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Insulating oil, if used, is to be tested in accordance with 9.2.7. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency over-speed governors are to be tested.

9.2.12 A general examination of the electrical equipment in areas which may contain flammable gas or vapour and/or combustible dust is to be made to ensure that the integrity of the safe type electrical equipment has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust-protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in good order. Tests are to be carried out to demonstrate the effectiveness of bonding straps for the control of static electricity. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation. Particular attention should be given to cable runs in way of articulated joints and breaks in process deck boundaries.

9.2.13 Shipboard Automatic and Remote-Control Systems. In addition to the requirements of Annual Surveys, the following parts are to be examined:

(a) Control actuators: All mechanical, hydraulic, and pneumatic control actuators and their power systems are to be examined and tested as considered necessary by the Surveyor.

(b) Electrical equipment: The insulation resistance of windings of electrical control motors or actuators is to be measured, with all circuits of different voltages above ground being tested separately to the Surveyor’s satisfaction.

(c) Unattended plants: Control systems for unattended machinery spaces are to be subjected to dock trials at reduced power on the propulsion engine to ensure the proper performance of all automatic functions, alarms and safety systems.

9.3 Docking Surveys and In-water Surveys

9.3.1 For production and oil storage units five years old and over, 9.2.11 is to be complied with. In addition, an electrical insulation resistance test of the circuits terminating in, or passing through, the dangerous areas is to be carried out.

■ *Section 10* **Boilers**

10.1 Frequency of surveys

10.1.1 All boilers, economisers, steam receivers, steam heated steam generators, thermal oil and hot water units intended for essential services, together with boilers used exclusively for non-essential services having a working pressure exceeding 3,5 bar and a heating surface exceeding 4,5 m^2 are to be surveyed internally. There is to be a minimum of two internal examinations during each five-year Special Survey cycle. The interval between any two such examinations is not to exceed 36 months. A general external examination is to be carried out at the time of the Annual Survey.

10.1.2 Consideration may be given in exceptional circumstances to an extension of the internal examination of the boiler, not exceeding three months beyond the due date. The extension may be granted after the following is satisfactorily carried out:

(a) External examination of the boiler.
(b) Examination and operational test of the boiler safety valve relieving gear (easing gear).
(c) Operational tests of the boiler protective devices.
(d) Review of the following records since the previous Boiler Survey:
  - Operation.
  - Maintenance.
  - Repair history.
  - Feedwater chemistry.

In this context, 'exceptional circumstances' means unavailability of repair facilities, essential materials, equipment or spare parts, or delays incurred by action taken to avoid severe weather conditions.

10.1.3 An external survey of boilers, including tests of safety and protective devices, and tests of safety valves using their relieving gear, is to be carried out annually within the range dates of the Annual Survey of the unit. For exhaust gas heated economisers, the safety valves are to be tested by the Chief Engineer at sea within the range dates of the Annual Survey. This test is to be recorded in the Log Book and reviewed by the attending Surveyor prior to crediting the Annual Survey.

10.2 Scope of surveys

10.2.1 At the surveys described in 10.1, the boilers, superheaters, economisers and air heaters are to be examined internally on the water-steam side and the fire side. Where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thicknesses of plates and tubes and sizes of stays are to be ascertained to determine a safe working pressure. The safety valves and principal mountings on boilers, superheaters and economisers are to be examined and opened up as necessary by the Surveyor. The adjustment of safety valves is to be verified during each boiler internal survey. Boiler safety valves and their relieving gear are to be examined and tested to verify their satisfactory operation. Safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable, provided that the valves lift at not more than 103 per cent of the approved design pressure. However, for exhaust gas heated economisers, if steam cannot be raised in port, the safety valves may be set by the Chief Engineer at sea, and the results recorded in the Log Book and reviewed by the attending Surveyor. The following records since the previous Boiler Survey are to be reviewed as part of the survey:

- Operation.
- Maintenance.
- Repair history.
- Feedwater chemistry.

The remaining mountings are to be examined externally and, if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

10.2.2 In addition to the requirements of 10.2.1, in exhaust gas heated economisers of the shell type, all accessible welded joints are to be subjected to a visual examination in order to identify any evidence of cracking. Non-destructive testing may be required for this purpose and may be requested by the Surveyor.

10.2.3 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

10.2.4 The oil fuel burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

10.2.5 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in Section 11.

10.2.6 At the annual general examination referred to in 10.1.1, the requirements of 2.3.8 and 2.3.9 are to be complied with.

10.2.7 For gas and crude oil burning systems, remote and/or automatic controls are to be examined and tested. Ventilating systems for ducts and machinery spaces are to be examined, tested and proven satisfactory.

■ *Section 11* Steam pipes

11.1 Frequency of surveys

11.1.1 Saturated steam pipes, and superheated steam pipes where the temperature of the steam at the superheater outlet is not over 450°C, are to be surveyed 10 years from the date of build (or installation) and thereafter at five-yearly intervals.

11.1.2 Superheated steam pipes where the temperature of the steam at the superheater outlet is over 450°C are to be surveyed five years from the date of build (or installation) and thereafter at five-yearly intervals.

11.1.3 At 10 years from the date of build (or installation) and thereafter at five-yearly intervals, all copper or copper alloy steam pipes over 76 mm external diameter supplying steam for essential services at sea are to be hydraulically tested to twice the working pressure.

11.2 Scope of surveys

11.2.1 At each survey, a selected number of main steam pipes, also of auxiliary steam pipes, which:
(a) are over 76 mm external diameter;
(b) supply steam for essential services at sea; and
(c) have bolted joints,
are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as is practicable, the pipes are to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipeline will be tested.

11.2.2 Where main and/or auxiliary steam pipes of the category described in 11.2.1(a) and (b) have welded joints between the lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, and the welds examined and, if considered necessary by the Surveyor, crack-detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

11.2.3 Where, on cylindrical boilers having smoke tube superheaters, the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smoke boxes are, at the surveys required by 11.1, to be included in the pipes selected for examination and testing, as defined in 11.2.1. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to be satisfied of the condition of the ends of the saturated steam pipes in the smoke boxes at each Boiler Survey and, if the Surveyor considers it necessary, a sample pipe is to be removed for examination.

11.2.4 At the surveys specified in 11.1.3, any of the copper or copper alloy pipes, such as those having expansion or other bends, which may be subject to bending and/or vibration, also closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

11.2.5 Where it is inconvenient for the Owner to fulfil all the requirements of a Steam Pipe Survey at its due date, the Classification Committee will be prepared to consider postponement of the survey, either wholly or in part.

■ *Section 12* Screwshafts, tube shafts and propellers

12.1 Frequency of surveys

12.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

12.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years, provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years, provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

12.1.4 All other shafts not covered by 12.1.1 to 12.1.3 are to be surveyed at intervals of $2^1/_2$ years.

12.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

12.1.6 Directional propeller and podded propulsion units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

12.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years, provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

12.1.8 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years.

12.2 Normal surveys

12.2.1 For self-propelled disconnectable units, screwshaft surveys held afloat at five-yearly intervals are to comply with the following:
(a) Measurement of bearing weardown.
(b) Verification of tightness of oil glands.
(c) Examination of propeller and fastenings.
(d) Verification on board of documentation of stern tube lubricating oil analysis carried out at regular intervals not exceeding six months. Each analysis, to be carried out on oil samples taken under service conditions and representative of oil within the stern tube, is to include the following minimum parameters:
  (i) Water content.
  (ii) Chloride content.
  (iii) Bearing material and metal particle content.
  (iv) Oil ageing (resistance to oxidation).
(e) Verification of records of oil consumption and bearing temperatures.

12.2.2 Directional propeller and podded propulsion units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

12.2.3 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers are to be generally examined so far as is possible and tested under working conditions afloat for satisfactory operation.

12.2.4 Podded propulsion unit screwshaft roller bearings are to be renewed when the calculated life at the maximum continuous rating no longer exceeds the survey interval. *See* Pt 5, Ch 9,6.3.8 of the Rules for Ships.

12.3 Complete surveys

12.3.1 If a self-propelled unit enters dry dock any time after five years from the previous dry-docking, date of build or date of commissioning, as applicable, a complete screwshaft survey is to be held.

12.3.2 All screwshafts are to be withdrawn for examination by LR's Surveyors. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment, at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers, where fitted, are to be opened up and the working parts examined, together with the control gear.

12.3.3 Directional propeller and azimuth thruster units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

12.3.4 Water jet units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

12.3.5 Dynamic positioning and/or thruster-assisted mooring and athwartship thrust propellers are to be generally examined so far as is possible and tested under working conditions afloat for satisfactory operation.

12.3.6 Podded propulsion unit screwshaft roller bearings are to be renewed when the calculated life at the maximum continuous rating no longer exceeds the survey interval. *See* Pt 5, Ch 9,6.3.8 of the Rules for Ships.

12.4 Screwshaft Condition Monitoring (SCM)

12.4.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the ShipRight descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered on the *ClassDirect Live* website:
(a) Lubricating oil analysis is to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
  (i) Water content;
  (ii) Chloride content;
  (iii) Bearing material and metal particles content;
  (iv) Oil ageing (resistance to oxidation).
(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.
(c) Oil consumption is to be recorded.
(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).
(e) Facilities are to be provided for measurement of bearing weardown.
(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

12.4.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings, are to be retained on board and audited annually.

12.4.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 12.3.2, provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 12.3.2 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction, the shaft will be required to be withdrawn in accordance with 12.3.2.

12.5 Modified Survey

12.5.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 12.1.1, provided that they are fitted with oil lubricated bearings and approved oil glands, and also for those in 12.1.2 and 12.1.3.

12.5.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller, a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts, including the propeller connection to the shaft, are to be examined as far as possible. Weardown is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

12.5.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

12.6 Special cases

12.6.1 The Classification Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 13* Drilling plant facility

13.1 Frequency of surveys

13.1.1 Drilling units having a **DRILL** notation in accordance with Pt 3, Ch 7 are to be surveyed annually in accordance with the requirements of 2.7. A Special Survey in accordance with the requirements of 13.2 is to be held at intervals not exceeding five years.

13.2 Scope of surveys

13.2.1 At each Special Survey, the Surveyor is to examine and test as necessary the following components of the drilling plant facility:

- Blow out preventer hoisting and handling equipment.
- Blow out preventer, diverter and their controls.
- Bulk storage.
- Choke manifold and associated valves.
- Drilling fluids circulation and cementing equipment.
- Drilling derrick hoisting, rotation and pipe handling equipment.
- Heave compensation equipment.
- Miscellaneous drilling equipment and equipment considered as part of the drilling installation.
- Well testing equipment.

13.2.2 Pressure vessels forming part of the drilling plant facility are to be examined in accordance with the requirements of Section 17, *see also* 2.5 and 2.7.

13.2.3 Piping systems for mud, cement and other systems subject to considerable erosion are to be examined for leaks and corrosion.

13.2.4 Safety and communication systems and hazardous areas are to be examined in accordance with Section 16.

■ *Section 14* Process plant facility

14.1 Frequency of surveys

14.1.1 Production and oil storage units having a **PPF** notation in accordance with Pt 3, Ch 8 are to be surveyed annually in accordance with the requirements of 2.5 and 2.7. A Special Survey in accordance with the requirements of 14.2 is to be held at intervals not exceeding five years.

14.2 Scope of surveys

14.2.1 At each Special Survey, the Surveyor is to examine and test as necessary the following components of the process plant facility:

- Major equipment of the production and process plant.
- Oil or gas processing system.
- Production plant safety systems.
- Production plant utility systems.
- Relief and flare system.
- Well control system.

14.2.2 Pressure vessels forming part of the process plant facility are to be examined in accordance with the requirements of Section 17, *see also* 2.5 and 2.7.

14.2.3 Piping systems and valves are to be examined for leaks and corrosion.

14.2.4 Safety and communication systems and hazardous areas are to be examined in accordance with Section 16.

■ *Section 15* Riser systems

15.1 Surveys – General

15.1.1 For units having a **PRS** notation in accordance with Pt 3, Ch 12, Riser Systems are to be surveyed as per a planned survey schedule agreed between the Owners and LR. This schedule should cover the extent, level and method of systematic examination of critical components of the system.

15.1.2 Extent and frequency of thickness measurements of components and areas where deterioration may be expected due to corrosion are to be included in the above schedule.

15.1.3 An agreed schedule for periodic surveys should be capable of determining condition of riser pipe structure and associated critical components, such as any cladding, bend stiffeners, end connectors, subsea buoyant supporting vessels, subsea valves, anti-corrosive coatings, etc.

15.1.4 This schedule should also include examination and testing of the riser system under working conditions at each Annual Survey.

15.1.5 Emergency shut-down systems with associated communication system, telemetry or instrumentation, pressure relief systems, systems for leak detection and protection against pressure surges are to be tested at each Annual Survey as per agreed procedures.

■ *Section 16* Safety and communication systems and hazardous areas

16.1 Frequency of surveys

16.1.1 Safety and communication systems and hazardous areas are to be surveyed annually in accordance with the requirements of 2.4. A Special Survey of safety and communication systems and hazardous areas in accordance with the requirements of 16.2 is to be held at intervals not exceeding five years.

16.2 Scope of surveys

16.2.1 The Surveyor is to examine and be satisfied as to the efficient condition of the following systems as required by Part 7:

(a) Fire and gas alarm indication and control systems.
(b) Systems for broadcasting safety information.
(c) Protection system against gas ingress into safe areas.
(d) Protection system against gas escape in enclosed and semi-enclosed hazardous areas.
(e) Emergency shut-down (ESD) systems.
(f) Protection system against flooding, including:
    (i) Water detection alarm systems for watertight bracings, columns, pontoons, footings, void watertight spaces and chain lockers.
    (ii) Bilge level detection and alarm systems on column-stabilised units and in machinery spaces on surface type units.
    (iii) Remote operation and indication of watertight doors and hatch covers and other closing appliances.
(g) Fire detection and extinguishing apparatus.

16.2.2 Satisfactory operation of automatic shut-down devices and alarms is to be verified.

16.2.3 Enclosed hazardous areas such as those containing open active mud tanks, shale shakers, degassers and desanders are to be examined and doors and closures in boundary bulkheads verified as effective. Ventilating systems including duct work, fans, intake and exhaust locations for enclosed restricted areas are to be examined, tested and proven satisfactory. Ventilating-air alarm systems are to be proven satisfactory. In hazardous areas electric lighting, electrical fixtures, and instrumentation are to be examined, proven satisfactory and verified as explosion-proof or intrinsically safe. A complete survey of electrical installations is to be carried out in accordance with Section 9. Electrical motors are to be examined, including closed-loop ventilating systems for large d.c. motors. Automatic power disconnect to motors in case of loss of ventilating air is to be proved satisfactory.

16.2.4 Piping systems for process plant and other systems in hazardous areas are to be checked for leaks, corrosion, and the safe operation of valves. Piping systems are to be tested when required by the Surveyor.

16.2.5 Pressure vessels and safety devices are to be subject to surveys in accordance with the requirements of Section 17.

■ *Section 17* Pressure vessels for process and drilling plant

17.1 Frequency of surveys

17.1.1 All pressure vessels are to be examined at the first Annual Survey after commissioning and subsequently at each Special Survey, *see* 2.3.8 and 2.3.9.

17.2 Scope of surveys

17.2.1 At the surveys described in 17.1, all pressure vessels are to be examined internally and externally. Principal mountings, supports and attachments to pressure vessels are to be examined, *see also* 17.2.4.

17.2.2 Where pressure vessels are so constructed that internal inspection is prevented by normal means, agreed tests are to be carried out to the satisfaction of the Surveyor.

17.2.3 Where, due to operational requirements, it is not possible to present all pressure vessels for inspection at the first Annual Survey, a sufficient number of pressure vessels from each system is to be examined, as agreed with the Surveyor, in order to establish the extent of corrosion and general condition of the system. The Owner's proposals for the inspection of the remaining pressure vessels are to be included in the Owner's planned maintenance and inspection procedure, as required by 1.6.

17.2.4 Selected pressure safety valves are to be bench tested in accordance with the requirements of 2.5 and 2.7. The Surveyor is to confirm that all pressure safety valves forming part of the process and drilling plant facility are examined and bench tested within each special survey cycle.

■ *Section 18* Inert gas systems

18.1 Frequency of surveys

18.1.1 Inert gas systems installed on board units intended for the storage of oil in bulk storage tanks are to be surveyed annually in accordance with the requirements of 2.6. A Special Survey of the inert gas system, in accordance with the requirements of 18.2, is to be held at intervals not exceeding five years.

18.2 Scope of surveys

18.2.1 At each Special Survey of the inert gas system, the inert gas generator, scrubber and blower are to be opened out as considered necessary and examined. Gas distribution lines and shut-off valves, including soot blower interlocking devices, as well as interlocking features and positive isolation for tank isolation are to be examined as considered necessary. The deck seal and non-return valve are to be examined. Cooling water systems including the effluent piping and overboard discharge from the scrubbers are to be examined. All automatic shut-down devices and alarms are to be tested. The complete installation is to be tested under working conditions on completion of survey.

18.2.2 When, at the request of an Owner, it has been agreed by the Classification Committee that the Complete Survey of the inert gas systems may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one fifth of the machinery is to be examined each year.

18.2.3 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

■ *Section 19* Classification of units not built under survey

19.1 General

19.1.1 When classification is desired for a unit not built under the supervision of LR's Surveyors, application should be made to the Classification Committee in writing.

19.1.2 Periodical Surveys of such units, when classed, are subsequently to be held, as in the case of units built under survey.

19.1.3 Where classification is desired for a unit which is classed by another recognised Society, special consideration will be given to the scope of the survey.

19.2 Hull and equipment

19.2.1 Plans showing the main scantlings and arrangements of the actual unit, together with any proposed alterations, are to be submitted for approval. These should comprise plans of the main hull/structure, including midship section, longitudinal and transverse sections, columns, decks, pontoons, bracings, legs and footings and such other plans as may be requested. If the class notation **DRILL** or **PPF** is to be assigned in accordance with Pt 3, Ch 7 or Ch 8 respectively, plans and documentation covering the major structures of the plant are to be submitted as may be requested.

19.2.2 If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the unit. The unit's Operations Manual is also to be submitted, *see* Pt 3, Ch 1,3.

19.2.3 Particulars of the process of manufacture, material grades and the testing of the material of construction are to be supplied.

19.2.4 In all cases, the full requirements of Section 5 are to be carried out as applicable. Units of recent construction will receive special consideration.

19.2.5 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. Loading instruments, where required, are to be in accordance with the Rules, *see* Ch 2,1.4 as applicable.

19.2.6 Safety and communication systems are to be verified in accordance with Section 16, *see also* Ch 3,1.1.

19.2.7 When the full survey requirements indicated in 19.2.4 and 19.2.5 cannot be completed at one time, the Classification Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

19.3 Machinery

19.3.1 To facilitate the survey, plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings are to be supplied:

- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Pumping arrangements at the forward and after ends of units with crude oil bulk storage tanks and drainage of cofferdams and pump-rooms.
- General arrangement of crude oil storage piping in tanks and on deck.
- Piping arrangements for bulk oil storage (F.P. 60°C or above, closed-cup test).
- Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.
- Arrangement and dimensions of main steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel and gas piping in connection with oil and gas burning installations.
- Oil fuel and bulk oil storage overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the unit's structure.
- Boilers, superheaters and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied).
- Azimuth thrusters.
- Electrical circuits.
- Hazardous areas.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- General arrangement of crude oil storage tank vents. The plan is to indicate the type and position of the vent outlets from any superstructure, erection, air intake, etc. Ventilation arrangements of storage tanks and/or ballast pump-rooms and other enclosed spaces which contain crude oil handling equipment.
- Safety and communication systems, *see* Pt 7, Ch 1.
- Jacking arrangements on self-elevating units.

19.3.2 Plans additional to those detailed in 19.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification. If the class notation **DRILL** or **PPF** is to be assigned in accordance with Pt 3, Ch 7 or Ch 8 respectively, plans and documentation covering the plant are to be submitted as may be requested.

19.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

19.3.4 For new units and units which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older units, the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Classification Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

19.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

19.3.6 Pressure vessels for process and drilling plant are to be examined as required for Special Surveys in Section 17.

19.3.7 The screwshaft is to be drawn and examined.

19.3.8 The steam pipes are to be examined and tested as required by Section 11.

19.3.9 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

19.3.10 Oil and gas burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

19.3.11 The electrical equipment is to be examined as required at Complete Surveys in Section 9.

19.3.12 Where an inert gas system is fitted on units intended for the storage of oil in bulk having a flash point not exceeding 60°C, the requirements of Pt 5, Ch 15,7 of the Rules for Ships apply.

19.3.13 The whole of the machinery, including essential controls, is to be tested under working conditions to the Surveyor's satisfaction.

19.3.14 Safety and communication systems and hazardous areas are to be examined as required at Special Surveys in Section 16. The requirements of Part 7 are to be complied with.

Section 20
Laid-up machinery

20.1 Survey requirements

20.1.1 Main and/or auxiliary propulsion, main and auxiliary steering gear and jack-up machinery not in use when the installation is operating at a fixed location may not be subject to periodic surveys as required by Sections 2 to 19. The machinery may be retained on board in laid-up status as per manufacturers' recommendations. However, all overdue surveys and reactivation requirements are to be dealt with prior to recommissioning. The reactivation requirements will be advised by LR on request.

20.1.2 If laid-up machinery is required to be used when the unit is disconnected from its moorings in an emergency, the periodic maintenance and operation schedules are to be in accordance with the manufacturers' recommendations and specially agreed to by LR.

Verification in Accordance with National Regulations for Offshore Installations

■ *Section 1* Conditions for verification

1.1 General requirements

1.1.1 It is the responsibility of Owners, Operators or Duty Holders to comply with all aspects of National Legislation applicable to units and installations engaged in petroleum activities in controlled waters.

1.1.2 When LR is requested by an Owner, Operator or Duty Holder to carry out verification in accordance with the Regulations of the coastal state authority, verification approval will be carried out in accordance with this Chapter.

1.1.3 Verification will be carried out to the specific provisions of the coastal state Regulations, as agreed with the Owner, Operator or Duty Holder, and appropriate to the proposed descriptive note and the type of unit and its function.

1.1.4 For the assignment of a National Authority descriptive note as defined in Ch 2,2.8.2, compliance with the coastal state Regulations will be considered in addition to the requirements of the Rules.

1.1.5 Verification will be based on LR's interpretation of the coastal state Regulations as applicable to the type of unit and its function. Where appropriate, the coastal state Regulations will take precedence over the Classification Rules if considered more stringent.

1.1.6 The verification approval will cover only the standards of design, construction, materials, workmanship, equipment, machinery, systems and installed plant as prescribed by the Regulations. Those aspects concerning operations, personnel equipment and the overall safety philosophy will be the responsibility of the Owner, Operator and/or Duty Holder.

1.1.7 LR can also advise Owners, Operators and/or Duty Holders on safety aspects and carry out risk analyses on their behalf, in order to provide the documentation required in the internal control system as stipulated by the coastal state.

1.2 Existing units

1.2.1 In the case of an existing classed mobile unit or installation which has been built in accordance with the legislation of a coastal state, other than that now required, LR will carry out a comparison with the coastal state Regulations as applicable. Deviations from the required coastal state Regulations which do not achieve an equivalent safety standard will be listed.

1.2.2 When an existing unit is converted or modified, any new modifications, technical equipment or system are to comply with the required coastal state Regulations, as applicable.

1.3 Recognised Codes and Standards

1.3.1 When the coastal state Regulations do not refer to specific Codes or Standards or define specific acceptance criteria, verification approval will be carried out in accordance with the class Rules or, where appropriate, in accordance with internationally recognised Codes and Standards. *See* Pt 3, Appendix A.

1.3.2 The class Rules and/or recognised Codes and Standards may also be used for verification approvals when they are considered to provide an equivalent standard to the coastal state Regulations or when additional requirements are considered necessary to meet LR's interpretation of the Regulations.

1.3.3 The mixing of different parts of Codes and Standards is to be avoided.

■ *Section 2* Documentation

2.1 Certificates

2.1.1 When the requirements of the coastal state Regulations have been complied with to LR's satisfaction, certificates and a design appraisal declaration will be issued.

2.1.2 In general, if there are non-compliances with any parts of the coastal state Regulations, the non-compliance items will be required to be cleared to LR's satisfaction before the issue of Interim Certificates of Classification by the Surveyors. Any deviations from the coastal state Regulations will be listed in the design appraisal declaration.

2.1.3 In the case of an existing unit, the requirements of 1.2 are to be complied with.

2.1.4 If there are any serious non-compliances with the coastal state Regulations which could have an effect on the overall safety of the vessel or installation, the National Authority descriptive note may be withheld at the discretion of the Classification Committee.

Section 3
Descriptive note

3.1 General

3.1.1 After verification approval has been carried out in accordance with 1.1.2 to LR's satisfaction, a National Authority descriptive note will be assigned by the Classification Committee in accordance with Ch 2,2.8.2.

3.1.2 National Authority descriptive notes may be utilised by the Owner, Operator or Duty Holder as part of the documentation required in the internal control system as stipulated by the coastal state Regulations.

3.1.3 When a National Authority descriptive note has been assigned in accordance with Ch 2,2.8.2, an additional entry will be made on the ClassDirect Live website.

Section 4
Survey requirements

4.1 General

4.1.1 New units, vessels and installations are to be built under LR's Special Survey and, during service, periodic surveys are to be carried out in accordance with Chapter 3.

4.1.2 When a National Authority descriptive note has been assigned in accordance with Ch 2,2.8.2, the condition of the unit, vessel or installation shall be documented by periodic surveys in accordance with the applicable coastal state Regulations.

4.1.3 A routine system for planning and implementation of periodic surveys for condition monitoring of the unit, vessel or installation in accordance with the applicable coastal state Regulations shall be proposed by the Owner, Operator and/or Duty Holder and be agreed with LR.

4.1.4 In general, condition monitoring surveys as required by the coastal state Regulations should be carried out at the same time as normal periodical class surveys in accordance with Chapter 3.

■ *Section 1* Application

1.1 General

1.1.1 Risk assessment techniques may be used to provide justification for the assignment of Class. Risk assessment techniques may be systematically applied to the whole of an installation or to individual systems, sub-systems or components.

1.1.2 Where risk assessment is applied to only part of an installation, the remainder of the installation is to be designed, constructed and maintained in accordance with the remaining Parts of these Rules.

1.1.3 Risk assessment provides a systematic method for the assessment of the risks posed to the safety and integrity of the installation or its parts.

1.1.4 Risk assessment may be used to define the basis of classification, by:

(a) identifying the hazards to safety and integrity of the installation, and evaluating them considering both consequence and frequency;

(b) identifying systems or elements of the installation that are critical in relation to the hazards; and

(c) defining performance standards which the critical systems or elements must meet to prevent, detect, control, mitigate or recover from, the identified hazards.

1.1.5 An installation, for which risk assessment has been applied in whole or in part, will be classed by Lloyd's Register (hereinafter referred to as 'LR'), provided LR has verified that all relevant critical elements are identified, are suitable for their intended purpose, and meet their required performance standards in design, construction, installation and function. Otherwise, classification will be subject to compliance with LR's Rules.

1.1.6 Similarly, an installation will continue to be classed by LR, provided LR has verified that all critical elements remain in good order and condition, and continue to meet their performance standards in operation. Otherwise, classification will be subject to continued compliance with LR's Rules.

1.1.7 It is the responsibility of the Owner/Operator to comply with any requirements of the National Administration. Where risk assessment results in the definition of performance standards different from those required by the National Administration or IMO Conventions, it is the responsibility of the Owner/Operator to obtain the necessary acceptance of the National Administration.

1.1.8 Classification using risk assessment relates to the performance standards of the identified critical elements for the safety and integrity of the installation. Operating procedures, including those developed in support of risk assessments for classification, are the responsibility of the Owner/Operator.

1.1.9 LR will implement a management scheme to control the process of applying risk assessment methodology to classification of an installation. Key stages subject to LR approval are detailed in this Chapter. The Owner/Operator is to accept and co-operate with the discipline of this management scheme.

1.1.10 LR will manage its own activities which are required to verify compliance with the agreed performance standards, by issuing project-specific work instructions to its design review and field personnel. The process will be documented to provide an audit record.

■ *Section 2* Definitions

2.1 Hazard

2.1.1 A 'hazard' is a situation with potential to cause harm or damage to the installation in terms of its safety and integrity.

2.2 Critical element

2.2.1 A 'critical element' is a part of the installation, or a system, sub-system or component, which is essential to the safety and integrity of the installation in relation to the identified hazards.

2.2.2 Critical elements are identified on the basis that:

(a) their failure could cause or contribute substantially to a reduction in installation safety or loss of integrity; or

(b) their purpose is to prevent or limit the effect of hazards which threaten such integrity.

2.3 Risk

2.3.1 'Risk' is the likelihood that a specified undesired event will occur within a specified period of time, or in specified circumstances.

2.4 Risk assessment

2.4.1 'Risk assessment' is the evaluation of the likelihood of specified undesired consequences to the safety and integrity of the installation, together with the value judgements made concerning the significance of the results.

2.5 Risk acceptance criteria

2.5.1 'Risk acceptance criteria' are the criteria to be applied to the results of the risk assessment, to demonstrate that the installation is capable of providing an acceptable level of safety and integrity.

2.6 Performance standards

2.6.1 Performance standards are statements that can be expressed in qualitative or quantitative terms, of the performance required of a critical element in order that it will manage the identified hazards to ensure the safety and integrity of the installation. Management of hazards may be achieved by the prevention, detection, control, mitigation, or recovery from these hazards.

2.7 Verification

2.7.1 Within the Classification process, 'Verification' is the confirmation by a process of examination by LR of the design, manufacturing, construction, installation and commissioning of the critical elements in order to show that they meet the required performance standards.

2.7.2 For the continuation of Classification in-service, 'Verification' is the confirmation by a process of examination by LR, taking into account the Inspection and Maintenance Plan activities, that the identified critical elements remain in good order and condition, and continue to meet their required performance standards in operation.

2.8 Inspection and maintenance plan

2.8.1 The 'Inspection and Maintenance Plan' is the Owner/Operator's programme of scheduled inspection and maintenance activities that ensure the required performance standards continue to be met in service, to maintain the safety and integrity of the installation against the identified hazards.

■ *Section 3* Methodology

3.1 General

3.1.1 Risk assessment requires the consideration of hazards and the likelihood of the hazards' consequences, and the means of hazard management.

3.1.2 The specific risk-based methodology used is to be in accordance with an applicable and recognised International or National Standard or Code.

3.1.3 The methodology is subject to approval by LR. The earliest engagement with class is encouraged when risk-based techniques are to be used as part of any design submission. This should happen far earlier than normal class approval, to ensure the approach adopted is acceptable, and does not result in project delay.

3.1.4 If risk assessment is used to examine individual systems, sub-systems, or components of an installation, a clear boundary marking the limit of such systems is to be identified.

3.1.5 These boundaries are subject to approval by LR.

3.2 Identification of hazards

3.2.1 Hazards that may threaten safety or integrity of the installation are to be identified.

3.2.2 Hazards to be considered are to include, but not be limited to, the following, as applicable:

- Blow out from wells.
- Hydrocarbon release, in particular, cryogenic jet, pool, drip or vapour.
- Fire and explosion incidents.
- Dropped objects.
- Ship and helicopter collision.
- Extreme weather and environment conditions.
- Loss of stability.
- Loss of structural integrity.
- Loss of systems essential to maintain the integrity of the installation.
- Loss of mooring system.

3.2.3 National Administration requirements may specify other hazards to be considered.

3.3 Ranking of hazards

3.3.1 The identified hazards are to be screened to provide a ranking of the hazards in terms of the consequences and likelihoods. Major hazards are those hazards that pose a significant threat to the safety and integrity of the installation.

3.3.2 The major hazards identified are subject to approval by LR.

3.3.3 Frequency analysis is an examination of the likelihood of the occurrence of hazardous events. The frequencies of occurrence of major hazards are to be estimated by suitable techniques, using appropriate occurrence or failure rate data. Both the likelihood of consequences and those consequences are to be analysed.

3.3.4 Consequence analysis is to consider the effects of hazardous events on the safety and integrity of the installation. Consequence analysis provides input to calculations of risk, and design information for risk reduction measures.

3.3.5 An assessment is to be performed to evaluate the availability of the emergency systems of the installation. Emergency systems are those systems that are required to operate when a hazard occurs, to protect the safety and integrity of the installation.

3.3.6 Emergency systems are to be assessed to evaluate their vulnerability to hazards that may occur.

3.4 Risk assessment

3.4.1 The risk is to be assessed for each of the possible failure modes identified. The risks from all the outcome events are to be considered together to assess the overall risk to the installation. This summation forms the baseline against which further risk reduction measures can be evaluated and a means of showing where the major risk contributors are in the installation.

3.4.2 The results of the risk assessment are subject to approval by LR.

3.5 Acceptance criteria

3.5.1 LR's Rules have been developed to the point where they achieve a standard of design and construction quality that ensures an acceptable level of safety and assurance of integrity of the installation. Provided that the Rules are followed throughout all the design and construction of the installation, this would ensure that the installation has an acceptable level of safety and assurance of integrity. Deviations from the Rules, using risk assessment as a method for justifying Class, must therefore demonstrate that such changes to the design and construction of an installation or its parts do not result in an unacceptable level of safety or integrity of the installation.

3.5.2 LR will require the Owner/Operator to develop risk acceptance criteria to be achieved by the design and maintained in service, to ensure the safety and integrity of the installation in line with the spirit and intent of LR's Rules.

3.5.3 Risk acceptance criteria are subject to approval by LR.

3.6 Identification of critical elements

3.6.1 Critical elements of the installation are to be identified in relation to the major hazards to safety and integrity of the installation. Critical elements provide the means to prevent, or to detect, control, mitigate and recover from, the hazards. Identification of critical elements is to be based on consequence of failure in relation to the reduction in safety and loss of integrity of the installation. Critical elements may be systems, sub-systems or components, of the installation.

3.6.2 Critical elements are subject to approval by LR.

3.7 Reducing the risks

3.7.1 For new construction, it is expected that the risk assessment will be initiated at the concept design stage. Opportunities may be identified for reducing the risks to the installation in its design. The aim is to achieve inherent safety by eliminating potential hazards. Where this is not practicable, a series of measures is to be applied which in order of preference prevent, detect, control, mitigate and allow recovery from the hazards.

3.8 Performance standards

3.8.1 Performance standards are to be developed for the critical elements in order that they will manage the identified hazards.

3.8.2 Performance standards are subject to approval by LR.

■ *Section 4* Verification – New Construction

4.1 General

4.1.1 LR requires to verify that all critical elements have been identified, are suitable for their intended purpose, and that they meet their required performance standards to ensure the safety and integrity of the installation.

4.1.2 Verification is to be based on performance standards that are subject to approval by LR for each critical system/element derived from the risk assessment.

4.1.3 LR will produce a project-specific Verification Plan for each case. This will cover the following key aspects:

(a) Review and approval of critical elements.
(b) Review and approval of performance standards derived from the risk assessment.
(c) Examination of design to confirm that the critical elements meet the agreed performance standards.
(d) Examination during manufacture, construction, installation and commissioning to confirm that the critical elements meet the approved performance standards.

4.1.4 LR will apply a verification management process for new construction projects. This will include the project-specific Verification Plan, and detailed work instructions for verification of each critical element at each stage of the project. The Owner/Operator is to co-operate with this management process and the requirements of the Verification Plan, and is to provide all necessary information and access for LR to carry out its verification tasks.

Section 5
Verification – In service

5.1 General

5.1.1 To maintain Classification in service, LR requires to verify that all critical elements for the operational phase have been identified, are suitable for their intended purpose, and that they remain in good repair and efficient condition and that they continue meet their required performance standards.

5.1.2 Verification is to be based on performance standards which are subject to approval by LR for each critical system/element derived from the risk assessment.

5.1.3 LR will produce a project-specific in-service Verification Plan for each case. This will cover the following key aspects:

(a) Review and approval of critical elements.
(b) Review and approval of performance standards derived from risk assessment.
(c) Review and approval of the Owner/Operator's Inspection and Maintenance Plan.
(d) Monitoring the execution of the Owner/Operator's Inspection and Maintenance Plan.
(e) Examination of the installation and records at intervals and frequency commensurate with level of development of Owner/Operator's Inspection and Maintenance Plan.
(f) Examination of design, construction, installation and commissioning of any modifications.

5.1.4 LR will develop the Verification Plan for in-service activities to suit the Owner/Operator's methodology for inspection and maintenance. This will detail the examination work associated with each critical system/element.

5.1.5 LR's review of the Owner/Operator's Inspection and Maintenance Plan will include:

(a) Management objectives and structure.
(b) Management systems.
(c) Planning/scheduling/reporting.
(d) Data evaluation and determination of inspection intervals.
(e) Methods of inspection/testing/monitoring.
(f) Competency, resourcing and training of personnel used for inspection and testing.
(g) Procurement, calibration and maintenance of maintenance and test equipment.
(h) Software systems for inspection and maintenance planning and recording.
(j) Quality Assurance and Quality Control.

5.1.6 Following review of the Owner/Operator's Inspection and Maintenance Plan, LR will develop a Verification Plan with an appropriate level and depth of examination to confirm that the elements identified as critical in relation to class continue to meet the approved performance standards. LR verification activities may include review of records, audit of procedures and activities of inspectors acting for the Owner/Operator, sample checks and physical examination of the installation, as appropriate.

5.1.7 Any revision of the Owner/Operator's Inspection and Maintenance Plan for the critical elements is to be carried out in consultation with LR and is subject to approval by LR.

5.1.8 The Owner/Operator is to co-operate with the requirements of the Verification Plan, and is to provide all necessary information and access for LR to carry out its verification tasks.

5.1.9 Verification activities will take place on a continuous basis as determined in the Verification Plan. Verification status reports will be generated by LR at appropriate intervals (usually annual) to facilitate renewals of any National Administration statutory certificates and maintenance of class.

5.1.10 The Verification Plan will also include a system for reporting and recording of conditions of class that will indicate clearly the timescales for any remedial actions.

5.1.11 Based on the findings of the Verification activities, LR reserves the right to increase or decrease the level and frequency of activities.

5.1.12 Class may be suspended or withdrawn, if deemed necessary, at the discretion of the Classification Committee.

Rules for the Manufacture, Testing and Certification of Materials

July 2014

Lloyd's Register

A guide to the Rules

and published requirements

Rules for the Manufacture, Testing and Certification of Materials

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e., Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g., *see* 2.1.3 (i.e., down to paragraph).

(b) In another set of Lloyd's Register Rules, e.g., *see* Pt 5, Ch 3,2.1 of the Rules and Regulations for the Classification of Ships.

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g., as shown in Fig. 2.3.5 (i.e., Chapter, Section and Figure Number).

(b) In another set of Lloyd's Register Rules, e.g., *see* Table 2.7.1 in Pt 3, Ch 2 of the Rules and Regulations for the Classification of Special Service Craft.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

July 2014

Chapter Contents

Materials

RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS

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■ *Section 1* Scope

1.1 General

1.1.1 Materials used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by Lloyd's Register (hereinafter refered to as LR), are to be manufactured, tested and inspected in accordance with these Rules.

1.1.2 Wrought, cast and extruded materials are to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapters 3 to 9 of these Rules. Mooring and anchoring equipment is to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapter 10. Manufacturers of these materials must be approved by LR according to the requirements in Sections 2 or 3. Only those materials within a manufacturer's scope of approval may be used.

1.1.3 Welding consumables are to comply with the requirements of Chapter 11 of these Rules.

1.1.4 Where welding is used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by LR, welding qualifications and tests shall be performed according to Chapter 12 of these Rules. All welding shall be performed according to Chapter 13 of these Rules.

1.1.5 Plastics materials are to comply with the requirements of Chapter 14 of these Rules.

1.1.6 The materials and components which are to comply with these requirements for the purposes of classification are defined in the relevant Rules dealing with design and construction.

■ *Section 2* Approval and survey requirements

2.1 Approval and survey requirements – General

2.1.1 Marine materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be made at works which have been approved by LR for the type and grade of product being supplied.

2.1.2 Materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be manufactured, tested and inspected under Survey according to the requirements of one of the following two schemes:
(a) The Materials Survey Scheme, *see* 2.3.
(b) The Materials Quality Scheme, *see* 2.4.

2.1.3 For the purposes of survey, LR Surveyors are to be allowed access to all relevant parts of the works, and are to be provided with the necessary facilities and information to enable them to verify that the manufacture is being carried out in accordance with the approved procedures. Facilities are also to be provided for the selection of test material, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

2.1.4 Where a production process, testing or examination of materials is sub-contracted, this must be with the approval of LR. Surveyors are to be allowed access to the sub-contractor's premises in order to conduct Surveys according to the requirements of these Rules.

2.1.5 Products manufactured in accordance with Chapters 11 and 14 are to be approved in accordance with the requirements therein. For these materials, approval is given for a specific product on a type approval basis, rather than the approved manufacturer/survey arrangements applied to materials covered by Chapters 3 to 10.

2.2 LR Approval – General

2.2.1 Unless specifically stated in other Chapters of these Rules, all LR approvals apply to materials used in applications intended for marine service, as described in 1.1.

2.2.2 The procedures for application for approval of manufacturers and products, the details of the information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's *Materials and Qualification Procedures for Ships* (MQPS). This is published in the CD Live section of LR's web site at http://www.lr.org.

2.2.3 LR publishes lists of approved manufacturers and approved products. The lists are published in the CD Live section of LR's website, http://www.lr.org.
The lists are as follows:

- *List of Approved Manufacturers of Materials*.
- *Approved Welding Consumables for Use in Ship Construction*.
- *Lists of Paints, Resins, Reinforcements and Associated Materials*.
- *Lists of Approved Anchors*.

2.2.4 For initial LR approval as an Approved Manufacturer for a particular material, the manufacturer is required to demonstrate to the satisfaction of LR, that the necessary manufacturing and testing facilities are available, and are supervised by suitably qualified personnel. A specified programme of tests is to be carried out under the supervision of LR Surveyors, and the results are to be to the satisfaction of LR.

2.2.5 If the results of the initial assessment of the manufacturer, and the test programme are considered satisfactory, the manufacturer will be added to the list of approved manufacturers of materials, and a certificate of approval will be issued to the manufacturer by LR, showing the scope of materials and grades covered by the approval. Initial approval will generally be under the Materials Survey Scheme, *see* 2.3.

2.2.6 Approved manufacturers who meet the entry requirements, may apply for approval under the Materials Quality Scheme, *see* 2.4.

2.2.7 When a manufacturer has more than one works, the manufacturer's approval shall only be valid for the works where the test programme was conducted.

2.2.8 It is the manufacturer's responsibility to advise LR of all changes to the manufacturing process parameters that may affect the application of the material, prior to the adoption of the changes in production. Additional approval tests may be required to maintain the approval.

2.2.9 Maintenance of approval is dependent on the manufacturer continuing to meet the requirements of the applicable sections of these Rules.

2.2.10 Where it is considered that an approved manufacturer is not maintaining its responsibilities to comply with these Rules, the approval may be suspended by LR until such time that agreed corrective and preventive actions are considered to have been satisfactorily carried out. If considered necessary, LR may require that the normal level of testing and inspection is increased.

2.2.11 In all instances, LR will reduce the scope of, or withdraw approval from, a manufacturer where it becomes apparent that the manufacturer is unable to maintain compliance with these Rules, or the scope of approval.

2.2.12 Where a manufacturer disagrees with any decisions made with regard to LR approval, they may appeal in writing to LR.

2.2.13 Any documents, data or other information received as part of the approval process, will be treated as strictly confidential, and will not be disclosed to any third party, without the manufacturer's prior written consent.

2.2.14 The approved works will be subject to a periodic inspection of all relevant parts of the works, at intervals not exceeding three years. The procedure for this periodic inspection is given in Book B of LR's *Materials and Qualification Procedures for Ships* (MQPS). This periodic inspection is in addition to the regular visits made according to 2.3.7.

2.3 Materials Survey Scheme

2.3.1 Materials according to Chapters 3 to 10 of these Rules and produced under the Materials Survey Scheme will be subject to Direct Survey by an LR Surveyor. The scheme requires the Surveyor to survey and certify all materials according to the requirements of these Rules.

2.3.2 Approved manufacturers are to request a survey of the material by an LR Surveyor, when required. Manufacturers must provide the Surveyor with details of the order, specification and any special conditions additional to the requirements of these Rules.

2.3.3 All mechanical tests required by these Rules are to be witnessed. The Surveyor may allow part of this task to be carried out by a member of the works staff by prior written agreement.

2.3.4 Before final acceptance, all materials are to be submitted to the specified tests and examinations under conditions acceptable to the Surveyor. The results are to comply with the Rules, and all materials are to be to the satisfaction of the Surveyor.

2.3.5 The specified tests and examinations are to be carried out prior to the despatch of finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer, and any tests or examinations that are not completed are to be carried out under survey at a subsequent stage of manufacture.

2.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabrication, such material is to be rejected, notwithstanding any previous certification.

2.3.7 In addition to witnessing test results, the Surveyor is responsible for ensuring that the manufacturing process, inspection, testing, identification and certification are properly conducted. As part of the Materials Survey Scheme, regular visits will be made to all relevant parts of the works to check for compliance against the requirements of these Rules, and to ensure that the manufacturer is maintaining the capability to consistently produce approved materials.

2.3.8 The Surveyor, when satisfied that the material fully meets the requirements of these Rules, will certify the material in accordance with Section 3 and the appropriate Chapter of these Rules.

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme, where the following requirements are met:

(a) The manufacturer has been approved by LR for a minimum of three years and continues to maintain their LR works approval according to 2.2.14; and
(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and
(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.2 Special consideration may be given to manufacturers who have not been approved under the Materials Survey Scheme, and may be considered onto the Materials Quality Scheme providing:

(a) They have a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum.
(b) They can demonstrate a history of satisfactory supply of materials, which LR deems to be equivalent to those for which approval under the Materials Quality Scheme is requested.

In this case, the initial assessment of the manufacturer will include the product testing regime, as required for initial approval under the Materials Survey Scheme, *see* 2.2.4.

2.4.3 The Scheme is based on a Scheme Certification Schedule, made between LR and each individual manufacturer. The schedule will stipulate:

(a) The scope of approved products covered by the approval.
(b) The process route applied by the manufacturer for each approved product.
(c) The arrangements for LR scheme, audits, including scope, frequency, schedule, etc.
(d) Agreed procedures for certification of approved materials.
(e) Information to be supplied periodically to LR by the manufacturer.
(f) Procedures for the use of the scheme mark.

2.4.4 The contents of the Scheme Certification Schedule are to remain confidential between LR and the manufacturer.

2.4.5 The Materials Quality Scheme is based on a technical audit approach, and is designed to complement the quality management systems audits performed to ISO 9001. The role of the Surveyor in scheme audits is to:

(a) Verify that the quality management system is being maintained and audited to the requirements of ISO 9001.
(b) Verify that the requirements of these Rules are being implemented.
(c) Verify that the requirements of this Scheme are being implemented.
(d) Perform Scheme audits, which focus on the technical aspects of the product realisation process, particularly with regard to Rule requirements.
(e) Perform witness testing as required.
(f) Verify the data supplied to LR periodically by the manufacturer, as part of the Scheme requirements.

2.4.6 The Materials Quality Scheme may be applied to any approved manufacturer who meets the eligibility requirements, and who applies to be approved under the scheme. If approved under the scheme, the manufacturer's name will appear on the List of Approved Manufacturers published by LR, with an indication that they are approved under this scheme.

2.4.7 The scheme is available to manufacturers producing approved materials according to Chapters 3 to 10 of these Rules.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in Book M of LR's *Materials and Qualification Procedures for Ships* (MQPS).

2.4.9 Where LR is satisfied that the manufacturer meets all of the requirements of the Scheme, and that it is appropriate for the products being manufactured, a Scheme Certification Schedule will be issued, which must be signed by an authorised representative of the manufacturer.

2.4.10 Once the Scheme Certification Schedule has been signed by both parties, LR will issue the manufacturer with a certificate of approval according to the Materials Quality Scheme.

2.4.11 Maintenance of approval will be according to the Scheme Certification Schedule, agreed between LR and the manufacturer, and these Rules.

2.4.12 It is the responsibility of the attending Surveyor, to perform regular Scheme audits at the manufacturer's works in accordance with the Scheme Certification Schedule, and the requirements of these Rules.

2.4.13 It is not the intention to repeat the audit according to ISO 9001, conducted by the recognised certification body. The Surveyor is, however, to be satisfied that these audits are being conducted effectively. Where appropriate, the Surveyor may conduct a partial audit to ISO 9001 to verify this.

2.4.14 Witness tests may be conducted as part of the Scheme audit. This will involve the selection of material, and the witness of sampling and testing according to the requirements of the appropriate chapter of these Rules. Such witness testing may be on LR grades, or materials which the Surveyor deems to be equivalent (for the purposes of audit testing only).

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is not the regular attending Surveyor. This assessment is in addition to the periodic inspection requirement made according to 2.2.14.

2.4.16 In the event of any change, which means that the manufacturer no longer meets the requirements for the Materials Quality Scheme (for example the loss of ISO 9001 approval), the Scheme certificate of approval will be revoked. The manufacturer will revert to the Materials Survey Scheme, and will be subject to survey according to that scheme.

■ *Section 3* Certification of materials

3.1 General

3.1.1 All materials subject to these Rules are to be supplied with appropriate certification, as required by the relevant requirements of these Rules. This will normally be a LR certificate or a manufacturer's certificate validated by LR, although a manufacturer's certificate may be accepted where allowed by the relevant requirements of these Rules.

3.1.2 Manufacturers approved under the Materials Quality Scheme are licensed to apply the scheme mark to manufacturer's certificates according to the requirements of the scheme, *see* 2.4.

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out by the manufacturer and which is in accordance with the requirements of these Rules, may be accepted. In this case, the certificate will include the following statement:
"We hereby certify, that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer, based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules, or the applicable National or International standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark. The certificates must also bear the following statement:
"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and scheme number MQS ……."

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR.

3.2 Materials Survey Scheme

3.2.1 The requirements for certification of materials according to the Materials Survey Scheme, are established by the relevant requirements of these Rules.

3.2.2 The manufacturer is to supply the surveyor with any additional customer order requirements that are in addition to the requirements of these Rules, when the request for the issue or validation of the certificate is made.

3.3 Materials Quality Scheme

3.3.1 Part of the certification schedule, will include an agreement for the manufacturer, to apply the scheme mark to manufacturer's certificates, relating to approved products within the scope of approval of the manufacturer.

3.3.2 The use of the scheme mark is governed by the following:

(a) The use of the scheme mark is not transferable. It is only to be used in conjunction with the manufacturer and works name and location shown on the certificate of approval.
(b) The scheme mark must be applied to all manufacturers' certificates relating to approved materials produced under the Scheme.
(c) In no circumstances is the scheme mark to be applied to test certificates relating to non-approved products.
(d) The scheme mark is not to be used in any way which may imply approval for products which are not covered within the manufacturer's scope of approval.
(e) Where a manufacturer is removed or suspended from the scheme, use of the scheme mark must cease immediately.

3.3.3 The certificate as given in 3.1.3(d) is to be validated by an authorised representative of the manufacturer. The size and position of the scheme mark and statement on the manufacturer's certificate must be agreed by LR.

3.3.4 Where manufacturers are approved under this scheme, the manufacturer's certificate, issued according to these requirements, fully meets the materials certification requirements of these Rules.

3.4 Electronic certification

3.4.1 Where these Rules allow the issue of manufacturers' test certificates, under either the Materials Survey Scheme or the Materials Quality Scheme, these may be issued in electronic format provided that:

(a) All tests and inspections have been satisfactorily completed, according to the requirements of these Rules.

(b) Procedures are in place to ensure that electronic certificates are only issued, according to the requirements of these Rules.
(c) The certification system is subject to regular inspection by the attending Surveyor.
(d) A copy of the electronic certificate is supplied to LR. This copy will be deemed to be the original of the test certificate.

3.4.2 In addition to the requirements of 3.4.1, for items certified under the Materials Survey Scheme, the LR office stamp and Surveyor's name may be applied electronically. This is only allowed where the Surveyor has access to the results of the relevant tests and inspections, and is able to authorise by access to the electronic system, the application of the LR office stamp and Surveyor's name on the test certificate. The name of the authorising Surveyor is to be the name included on the certificate. The authorisation may be conducted electronically either at the manufacturers' works, or remotely by the Surveyor.

3.4.3 If the LR office stamp and name are being applied electronically according to 3.4.2, then the manufacturer is to ensure that the Surveyor is provided with all relevant information regarding the customer order, when the request for authorisation is made.

■ *Section 4* General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Item: A single forging, casting, plate, tube or other rolled product as delivered.
Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.
Batch: A number of similar items or pieces presented as a group for acceptance testing.
Wide flat: Flat product of a width over 150 mm, up to and including 1250 mm and thickness generally over 4 mm. Edges are square cut, i.e., hot rolled on the four sides. Supplied in lengths, not coils.
Plate/sheet: Flat rolled product whereby the edges are allowed to deform freely. Supplied flat and generally in square or rectangular shapes with a width of 600 mm or over, but other shapes may also apply.

4.1.2 Where a manufacturer purchases semi-finished products (e.g., slabs) for the purpose of re-processing (e.g., rolling), the manufacturer is to ensure that the materials are from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer. The aim of chemical analysis, dimensions, surface and internal quality checks are to be agreed between the manufacturer and purchaser. The semi-finished materials must be supplied with appropriate certification, according to these Rules.

4.1.3 It is the responsibility of the manufacturer, to ensure compliance with all relevant aspects of these Rules. All deviations are to be recorded as non-compliances, and brought to the attention of the Surveyor, along with corrective actions taken. Failure to do this is considered to render the material as not complying with these Rules.

4.1.4 The manufacturer is to maintain all test and inspection records required by these Rules for at least seven years. Records are to be made available to LR on request.

4.1.5 Where material is produced which does not meet all aspects of these Rules, the manufacturer may apply to LR for a concession to certify the material as approved. LR will consider each application on a case-by-case basis, although concession will only normally be granted in exceptional circumstances. If the concession is granted, a formal written numbered concession will be issued to the manufacturer. The concession number must be applied to the approval certificate, whether it is an LR certificate or a validated manufacturer's certificate.

4.2 Chemical composition

4.2.1 The ladle analysis used for certification purposes is to be determined after all alloying elements have been added and sufficient time allowed for such additions to equalise throughout the ladle.

4.2.2 The method of taking samples is to ensure that the reported analysis is representative of the cast. In addition, the manufacturer must determine and certify the chemical composition of every heat of material.

4.2.3 Where more than one sample is taken, the method of averaging for the final certificate result and the determination of acceptable variations in composition are to be agreed with the Surveyor.

4.2.4 The chemical composition of ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyor.

4.2.5 The analysis is to include the content of all the elements detailed in the relevant Sections of the Rules and, where appropriate, the National or International Standard applied.

4.2.6 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests but, where this is not practicable, an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with an appropriate International or National Standard specification.

4.3 Heat treatment

4.3.1 Materials are to be supplied in the condition specified in, or permitted by, the relevant Chapters of these Rules.

4.3.2 Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components, which require heat treatment, alternative methods will be specially considered.

4.3.3 The manufacturer is to maintain the records, including the temperature charts of all heat treatments, for at least seven years.

4.4 Test material

4.4.1 Sufficient test material is to be provided for the preparation of the test specimen detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

4.4.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in subsequent Chapters of these Rules.

4.4.3 All test material is to be selected by the Surveyor or an authorised deputy and identified by suitable markings which are to be maintained during the preparation of the test specimens.

4.5 Mechanical tests

4.5.1 The dimensions, number and direction of test specimens are to be in accordance with the requirements of Chapter 2 and the specific requirements for the product.

4.5.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Chapters. One individual value may be less than the required average value, provided that it is not less than 70 per cent of that value.

4.5.3 In the Rules, mechanical properties are specified in SI units, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate conversions given in Table 1.4.1. It is preferred that test results be reported in SI units, but alternative units may be used provided that the test certificate gives, in the same units, the equivalent specification values.

Table 1.4.1 Conversions from SI units to metric and Imperial units

1 N/mm^2 or MPa	=	0,102 kgf/mm^2
1 N/mm^2 or MPa	=	0,0647 tonf/in^2
1 N/mm^2 or MPa	=	0,145 x 10^3 lbf/in^2
1J	=	0,102 kgf m
1J	=	0,738 ft lbs
1 kgf/mm^2	=	9,81 N/mm^2 or MPa
1 tonf/in^2	=	15,4 N/mm^2 or MPa
1 lbf/in^2	=	6,89 x 10^{-3} N/mm^2 or MPa
1 kgf m	=	9,81 J
1 ft lbf	=	1,36 J

4.6 Re-test procedures

4.6.1 Re-test procedures are to be in accordance with the requirements of Ch 2,1.4.

4.7 Rectification of defective material

4.7.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with any applicable requirements of subsequent Chapters of these Rules and to the satisfaction of the Surveyor.

4.7.2 The repair of defects by welding, can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair, are to be in accordance with the appropriate specific require-ments and are to be to the satisfaction of the Surveyor.

4.7.3 Manufacturers wishing to carry out welding work must have at their disposal the necessary workshops, lifting gear, welding equipment, pre-heating, and where necessary annealing facilities and testing devices, as well as certified welders and supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.8 Identification of materials

4.8.1 The manufacturer is to adopt a system of identification, which will enable all finished materials to be traced to the original cast, and the Surveyors are to be given full facilities for tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

4.8.2 Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

4.8.3 Where hard stamps such as the LR brand stamp are issued to manufacturers to carry out the stamping on behalf of LR, the procedure for issue, maintenance and use of stamps is to be agreed in writing.

4.8.4 Hard stamping is to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e., the dried film is not to contain any of these elements in quantities of more than 250 ppm.

4.8.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

■ *Section 5* Non-destructive examination

5.1 General NDE requirements

5.1.1 Prior to the final acceptance of materials, surface inspection and verification of dimensions, non-destructive examination is to be carried out in accordance with the requirements detailed in this Section and subsequent Chapters of these Rules.

5.1.2 It is the manufacturer's responsibility for maintaining the required tolerances and making the necessary measurements. Periodic surveys by the Surveyor do not absolve the manufacturer from this responsibility.

5.1.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by a suitable method.

5.1.4 Acceptance criteria are detailed in subsequent Chapters of these Rules. Alternative specifications may be submitted for consideration, provided they demonstrate equivalence to these Rules.

5.2 Personnel qualifications

5.2.1 The shipyard, fabricator or manufacturer is to ensure that personnel carrying out non-destructive examination or interpreting the results of non-destructive examination are qualified to the appropriate level of a nationally recognised scheme such as ISO 9712, PCN, ACCP or SNT-TC-1A. Level 1 personnel are not permitted to interpret results to Codes or Standards.

5.2.2 When certification of personnel is made on an in-house basis under a scheme such as SNT-TC-1A, practical examinations are to be relevant to material, product type, joint configuration, material thickness and acceptance criteria of items inspected for Classification purposes.

5.2.3 Personnel qualifications of NDE operators are to be randomly checked by the Surveyor.

5.3 Non-destructive examination methods

5.3.1 Non-destructive examination methods are to comply with the relevant requirements of these Rules.

5.4 Non-destructive examination procedures

5.4.1 All non-destructive examinations are to be carried out to a procedure that is representative of the item under inspection. As a minimum the procedures are to be in accordance with the following:

(a) Procedures are to identify the component to be examined, the NDE method, equipment to be used and the full extent of the examinations including any test restrictions.
(b) Procedures are to specify the qualification and certification requirements of the inspection personnel to be employed.
(c) Procedures are to state the degree of surface preparation required and the methods of preparation to be used before the examinations are made.
(d) Procedures are to state the reference standards for testing and the acceptance criteria to be applied to the results of the inspections.
(e) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
(f) Procedures are to identify any requirements for increasing the extent of applied NDE where defects have been found during spot examination.
(g) Procedures are to identify reporting requirements.
(h) Procedures are to be reviewed by the Surveyor to ensure they are appropriate for the product type.
(j) Procedures for radiography are to specify the acceptable optical density within the area of interest on the radiograph.
(k) The minimum optical density within the area of interest on a radiograph is to be equal to or greater than 2,0 for gamma ray and 1,8 for X-ray. A maximum density of 4,0 is acceptable.
(l) Procedures are to include the method and requirements for equipment calibrations and functional checks.
(m) Procedures are to be approved by an operator qualified to a minimum of Level III in accordance with a recognised standard.
(n) The Surveyor will review procedures for compliance with this Section.

5.4.2 The shipyard, fabricator or manufacturer may submit other Codes or Standards for consideration by LR, providing they are equivalent to these Rules. Where no agreed acceptance standard is in place, the acceptance levels contained in the subsequent Chapters of these Rules are to apply.

5.4.3 In the event that proposed acceptance criteria are not considered to be equivalent to these Rules, the criteria may be submitted for special consideration.

5.5 Non-destructive examination reports

5.5.1 NDE reports are to include all information required to identify how the examination was executed and are to include the following information where appropriate:

(a) Date of test.
(b) Name and qualification of operator with signatures of the operator.
(c) Details of the component identification, description of test location and volume examined.
(d) Heat treatment status.
(e) Weld type, procedure and configuration.
(f) Surface condition.
(g) Test procedure.
(h) Equipment used.
(j) Test results with a map or record of reportable and/or reject indications, giving location, dimensions and nature of indications.
(k) Reference to acceptance criteria and evaluation in accordance to these criteria.
(l) Material type and thickness.
(m) Calibration.

■ *Section 6* References

6.1 General

6.1.1 The locations of National and International Standards referenced in these Rules are shown in Table 1.6.1.

Table 1.6.1 List of National and International Standards (*see continuation*)

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001: 2008 SNT-TC-1A:2012 ISO 9712:2012
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1: 2009 ISO 185: 2005 ISO 2566-1: 1999 ISO 148-1: 2009 ISO 7500-1: 2004 ISO 6506-1: 2006 ISO 6506-2: 2006 ISO 6506-3: 2006 ISO 6507-1: 2006 ISO 6507-2: 2006 ISO 6507-3: 2006 ISO 6508-1: 2006 ASTM E23-Rev C (2012)
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160: 1999 ASTM A578-07 ASTM E112-Rev C (2012) ISO 7452:2002 ASTM E208-06 ASTM E381-01 (2006) ASTM A255-2010
Chapter 4 – Steel Castings	ASTM G48-11 ISO 1161: 1984/Amendment 1: 2007
Chapter 5 – Steel Forgings	ASTM E112-12 ASTM G48-11
Chapter 8 – Aluminium Alloys	ASTM G66-99 (2005)e1 ASTM G67-04
Chapter 9 – Copper Alloys	ASTM E272-2010 EN 1057: 2006 +A1: 2010
Chapter 10 – Equipment for Mooring and Anchoring	ISO 1704: 2008 ISO 1834: 1999 ISO 4565: 1986 ASTM E112-2010 ASTM E381-01 (2006) ASTM A255-2010
Chapter 11 – Approval of Welding Consumables	ISO 3690: 2000 ISO 10042: 2005 ASTM G48-11
Chapter 12 – Welding Qualifications	ISO 6947: 2011 ISO 5817: 2007 ISO 6520-1: 2007 ISO 6507-1: 2005 ISO 10042: 2005 ASTM G48-11 ISO 25239-3: 2011 ISO 25239-4: 2011
Chapter 13 – Requirements for Welded Construction	ISO 9712/Cor1: 2006 ISO 6520-1: 2007 SNT TC-1A-2011 AWS D3.6M:2010 ISO 10042: 2005 ISO 25239-5: 2011

Table 1.6.1 List of National and International Standards (*conclusion*)

Rule reference	Standard
Chapter 14 – Plastics Materials	ISO 527-2: 2012 ISO 178: 2010 ISO 62: 2008 ISO 75-2: 2004 ISO 604: 2002 ISO 527-4: 1997 ISO 14125: 1998/ amd1:2011 ISO 14130: 1997/ corr1:2003 ISO 1172: 1996 ISO 1922- 2012 ASTM C273/C273M-11 ASTM C393/C393M-11 ISO 845- 2006 ASTM C297/C297M-04 ISO 844-2007 ISO 1922-2001 ISO 180-2000 ASTM D2583-07 BS 2782-10 Method 1001: 1977 ISO 175: 2010 BS 1088-1: 2003 BS 1088-2: 2003

Section

■ Section 1 General requirements for testing

1.1 Preparation of test specimens

1.1.1 The requirements specified below detail all the tests that may be applied to metallic materials. The specific tests and the test specimen types required for each material type, grade and product type are detailed in the subsequent Chapter of these Rules.

1.1.2 Where test material is cut from products by shearing or flame cutting, a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

1.1.3 Test specimens are to be prepared in such a manner that they are not subjected to any significant work hardening, cold straining or heating during straightening or machining.

1.1.4 Test samples are not to be removed from the material they represent until heat treatment is complete. For castings in cases where test samples are separately cast, the castings and samples are to be heat treated together.

1.1.5 Dimensional tolerances are to comply with a relevant ISO specification.

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by organisations of standing that have been approved or recognised by a National Authority and are to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

1.2.2 Tensile testing machine load cells are to be calibrated with an accuracy of ± one per cent in accordance with ISO 7500-1 or another recognised National Standard.

1.2.3 Impact tests are to be carried out on Charpy V-notch machines calibrated to ISO 148 or ASTM E23 dependent on the testing machine type. The testing machines are to be calibrated using either a direct or indirect method. Other National Standards equivalent to ISO 148 may be considered.

1.2.4 Hardness testing machines, together with their associated measuring microscopes, are to be directly and indirectly calibrated to ISO 6506-2, 6507-2 or equivalent standards applicable to the type of hardness test. Other National Standards equivalent to ISO 6507-2 and 6506-2 standards may be considered. Routine hardness checks with standard hardness blocks calibrated to ISO 6506-3 or ISO 6507-3 or equivalent are to be carried out at a frequency which demonstrates calibration consistency.

1.3 Discarding of test specimens

1.3.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test.

1.3.2 In addition to the discarding of test specimens as indicated in 1.3.1, a tensile test specimen may also be discarded when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than one-quarter of the gauge length.

1.4 Re-testing procedures

1.4.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same test sample, or if sufficient material is not available, a further representative sample taken from the item under test. For acceptance of the material, satisfactory results are to be obtained from both of these additional tests.

1.4.2 Where the result of any test taken from a weld procedure approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using the same conditions as the original test weld. For acceptance, satisfactory results are to be obtained from both of these additional tests.

1.4.3 Where the result of any test taken from a welding consumable approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the same number of runs) as the original assembly, only the duplicate re-test specimens need be prepared and tested. For acceptance of a weld consumable batch, satisfactory results are to be obtained from both of these additional tests.

1.4.4 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that, of the original set tested, not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

1.4.5 The additional tests detailed in 1.4.1 and 1.4.2 are, where possible, to be made on material adjacent to the original samples. For castings, where insufficient material remains in the original test samples, the additional test may be made on other test samples representative of the castings. *See also* 1.3 for discarding of test specimens.

1.4.6 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both or these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.4.7 When a batch of material is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.4.8 At the option of the manufacturer, rejected material may be resubmitted as another grade and may then be accepted, provided that the test results comply with the appropriate requirements.

1.4.9 When material which is intended to be supplied in the 'as-rolled' or 'hot-finished' condition fails test, it may be suitably heat treated and resubmitted for test. Similarly, materials supplied in the heat treated condition may be reheat treated and resubmitted for test. Unless otherwise agreed by the Surveyor, such reheat treatment is to be limited to one repeat of the final heat treatment cycle.

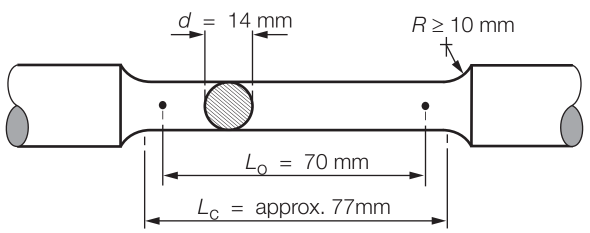
■ *Section 2* **Tensile tests**

2.1 Dimensions of test specimens

2.1.1 Proportional test specimens with a gauge length L_o of $5{,}65\sqrt{S_o}$ or $5d$, where S_o is the cross-sectional area, d the diameter and L_c the parallel test length, have been adopted as the standard form of test specimen, and in subsequent Chapters in these Rules the minimum percentage elongation values are given for test specimens of these proportions.

2.1.2 The gauge length is to be greater than 20 mm and may be rounded off to the nearest 5 mm provided that the difference between the adjusted gauge length and the calculated one is less than 10 per cent of the calculated gauge length.

2.1.3 For forgings and castings (excluding those in grey cast iron) proportional test specimens of circular cross-section are to be machined to the dimensions shown in Fig. 2.2.1.

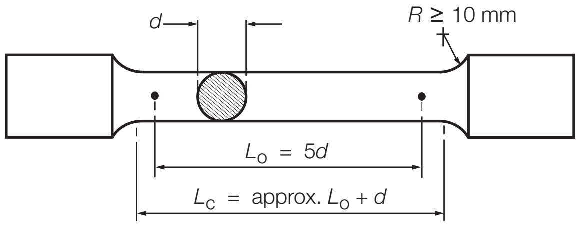


NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 20$ mm

Fig. 2.2.1
Test specimen dimensions for forgings and castings – I

2.1.4 For hot rolled bars and similar products, the test specimens are to be as in Fig. 2.2.1, except that for small sizes they may consist of a suitable length of bar or other product tested in the full cross-section.

2.1.5 As an alternative to 2.1.3 and 2.1.4, proportional or non-proportional test specimens of other dimensions may be used, subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. Where the size of proportional test specimens is other than as shown in Fig. 2.2.1, the general dimensions are to conform with Fig. 2.2.2.



NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 1{,}5d$

Fig. 2.2.2
Test specimen dimensions for forgings and castings – II and aluminium alloys

2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in Fig. 2.2.3 or Fig. 2.2.4. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in Fig. 2.2.1 may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.

2.1.7 As an alternative to 2.1.6, test specimens with a width of other than 25 mm may be used subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. A ratio of width/thickness of 8:1 should not be exceeded.

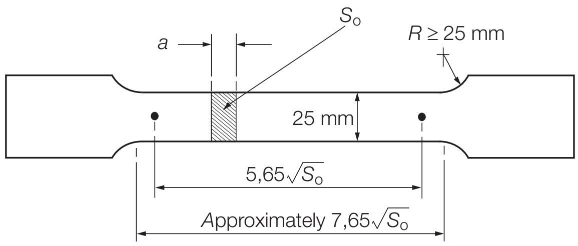
2.1.8 For pipes and tubes, the test specimens may consist of a suitable length tested in full cross-section with the ends plugged. The gauge length is to be $5{,}65\sqrt{S_o}$ or 50 mm, and the length of the test specimen between the grips or plugs, whichever is the smaller, is to be not less than the gauge length plus D, where D is the external diameter. Alternatively, test specimens may be prepared from strips cut longitudinally and machined to the dimensions shown in Fig. 2.2.5 or Fig. 2.2.6. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.
The cross-sectional area of this type of test specimen is to be calculated from:

$S_o = ab$

where

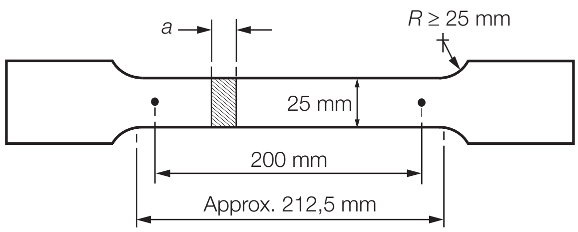
S_o = cross-sectional area
a = average radial thickness
b = average width

Test specimens of circular cross-section may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions shown in Fig. 2.2.1, with their axes located at the mid-wall thickness.



a = thickness of material

Fig. 2.2.3
Test specimen dimensions for plates, strip and sections – I and aluminium alloys



a = thickness of material

Fig. 2.2.4
Test specimen dimensions for plates, strip and sections – II

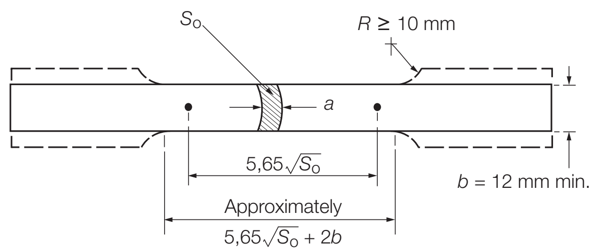


Fig. 2.2.5
Test specimen dimensions for pipes and tubes – I

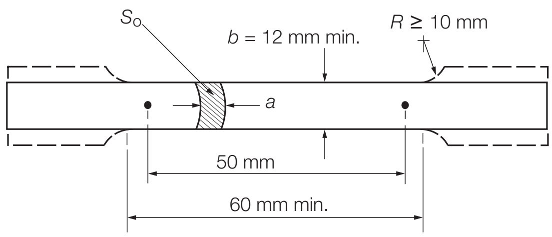


Fig. 2.2.6
Test specimen dimensions for pipes and tubes – II

2.1.9 For wire, the test specimen may consist of a suitable length tested in full cross-section. The gauge length is to be 200 mm and the parallel test length 250 mm.

2.1.10 For grey iron castings, the test specimens are to be machined to the dimensions shown in Fig. 2.2.7 or Fig. 2.2.8.

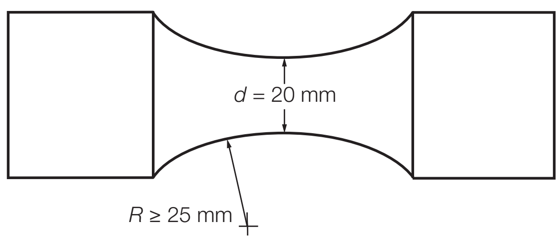


Fig. 2.2.7
Test specimen dimensions for grey iron castings – I

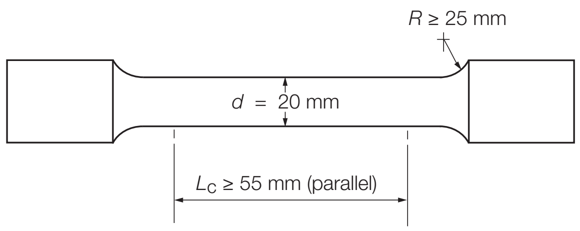


Fig. 2.2.8
Test specimen dimensions for grey iron castings – II

2.1.11 For aluminium alloy plates and sections of thickness, *a*, less than or equal to 12,5 mm; the dimensions of rectangular cross-sectioned test specimens are to be as shown in Fig. 2.2.3. The rectangular cross-sectioned test specimen surfaces should remain as rolled/extruded. Where the thickness, *a*, is greater than 12,5 mm the test specimens are to be of round type as shown in Fig. 2.2.2.

2.1.12 Deposited weld metal tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.9, and may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

2.1.13 Butt weld tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.10. For thicknesses of more than 2 mm, the test width is to be 25 mm. For thicknesses less than 2 mm, the test width is to be reduced to 12 mm. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

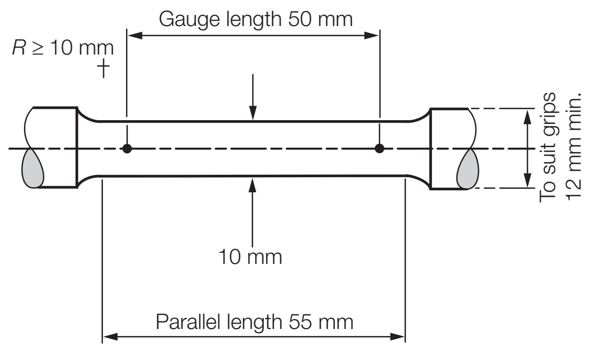


Fig. 2.2.9
Test specimen for deposited weld metal tensile

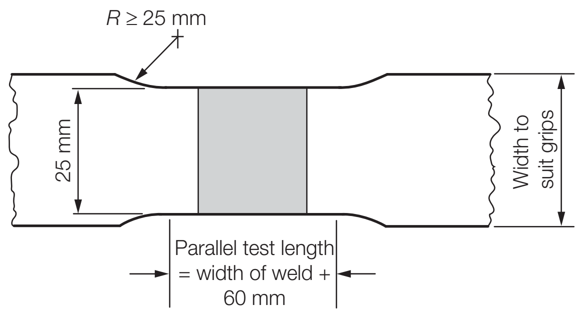


Fig. 2.2.10 Test specimen for butt weld

2.1.14 Through-thickness tensile test specimens may be, at the option of the steelmaker, either plain test specimens or test specimens with welded extensions in accordance with a Recognised Standard. The extension pieces are to be of steel with a tensile strength exceeding that of the plate to be tested and may be attached to the plate surfaces by manual, resistance or friction welding carried out in such a way as to ensure a minimal heat affected zone.

2.1.15 Tolerances on tensile specimen dimensions are to be in accordance with ISO 6892-1 or another Recognised Standard as appropriate.

2.2 Definition of yield stress for steel

2.2.1 The yield phenomenon is not exhibited by all the steels detailed in these Rules but, except for austenitic and duplex stainless steels, the term ‘yield stress’ is used throughout when requirements are specified for acceptance testing at ambient temperature. For the purposes of the Rules, the terms ‘yield stress’ and ‘yield strength’ are to be regarded as synonymous.

2.2.2 Where reference is made to 'yield stress' in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or, where this is not clearly exhibited, the 0,2 per cent proof stress or the 0,5 per cent proof stress under load is to be determined. In cases of dispute, the 0,2 per cent proof stress is to be determined.

2.2.3 For austenitic and duplex stainless steel products and welding consumables, both the 0,2 and the 1,0 per cent proof stresses are to be determined.

2.3 Procedure for testing at ambient temperature

2.3.1 Except as provided in 2.3.5, the elastic stress rate for the determination of the upper yield for steels and copper alloys is to be between 6 and 60 N/mm^2 per second and between 2 and 20 N/mm^2 per second for aluminium. After reaching the yield or proof load, the straining rate may be increased to a maximum of 0,008s^{-1} for the determination of the tensile strength.

2.3.2 For steel, the upper yield stress is to be calculated from:

(a) the value of stress measured at the commencement of plastic deformation, or

(b) on a load/extension diagram using the value of stress measured at the first peak obtained during yielding even when the peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.

2.3.3 When a well defined yield point cannot be obtained, the 0,2 or 1,0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and a distance from it where the amount represents 0,2 or 1,0 per cent of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 or 1,0 per cent proof stress can be calculated.

2.3.4 For stainless steels, the 1,0 per cent proof stress and/or 0,2 per cent proof stress is specified as required by the relevant Chapters in these Rules.

2.3.5 For the determination of the tensile strength of flake graphite cast iron, the stress rate is not to exceed 10 N/mm^2 per second.

2.3.6 A measured elongation value is to be regarded as valid only if the fracture occurs within the gauge length and at least the following distances from the gauge marks:

Round test specimen:	1,25d
Flat test specimen:	a plus width of specimen

The measurement is valid irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value, and this is to be stated in the test report.

2.4 Equivalent elongations

2.4.1 When a gauge length other than $5{,}65\sqrt{S_o}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:

$$A = \frac{A_R}{2}\left(\frac{L_o}{\sqrt{S_o}}\right)^{0{,}40}$$

where

A_R = actual measured percentage elongation of test specimen

S_o = actual cross-sectional area of test specimen

L_o = actual gauge length of test piece

A = equivalent percentage elongation for a test specimen with a gauge length of $5{,}65\sqrt{S_o}$.

2.4.2 Alternatively, where a number of test specimens of similar material and dimensions are involved, the actual percentage elongation values may be recorded, provided that the equivalent specified minimum elongation value appropriate for the test specimen dimensions is calculated from the formula in 2.4.1 and is recorded on the test certificate.

2.4.3 For proportional test specimens having a gauge length other than $5{,}65\sqrt{S_o}$, the equivalent elongation may be calculated using the following factors (d is the diameter of the test specimen):

Actual gauge length	Factor for equivalent elongation on $5{,}65\sqrt{S_o}$
$4\sqrt{S_o}$	x 0,870
$8{,}16\sqrt{S_o}$	x 1,158
$11{,}3\sqrt{S_o}$	x 1,317
4d	x 0,916
8d	x 1,207

2.4.4 For non-proportional test specimens with gauge lengths of 50 mm and 200 mm, the equivalent elongation values tabulated in ISO 2566 are to apply.

2.4.5 The above conversions are reliable only for carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalised, or normalised and tempered condition.

2.4.6 For alloy steels in the quenched and tempered condition, the following conversions may be used for proportional test specimens with a gauge length of $4\sqrt{S_o}$:

Actual percentage elongation on $4\sqrt{S_o}$	Equivalent elongation on $5{,}65\sqrt{S_o}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

2.4.7 Any proposals to use conversion factors for equivalent elongation values for the following materials are to be agreed with the Surveyors:
(a) Carbon, carbon-manganese and alloy steels in the normalised or normalised and tempered condition with a tensile strength exceeding 700 N/mm^2.
(b) Cold-worked steels.
(c) Austenitic stainless steels.
(d) Non-ferrous alloys.

2.5 Procedure for testing at elevated temperatures

2.5.1 The test specimens used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm^2. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practicable dimensions.

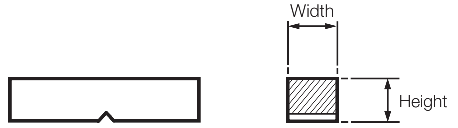
2.5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ±5°C.

2.5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0,1 to 0,3 per cent of the extensometer gauge length per minute.

2.5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens

Dimension	Nominal	Tolerance
Length, in mm	55	±0,60
Height, in mm, *see* Note 1	10	±0,075
Width, in mm, *see* Note 1		
– standard specimen	10	±0,11
– standard subsidiary specimen	7,5	±0,11
– standard subsidiary specimen	5	±0,06
Angle of notch	45°	±2°
Height below notch, in mm	8	±0,075
Root radius, in mm	0,25	±0,025
Distance of plane of symmetry of notch from ends of test piece, in mm, *see* Note 1	27,5	±0,42, *see* Note 2
Angle between plane of symmetry of notch and longitudinal axis of test piece	90°	±2°
Angle between adjacent longitudinal faces of test piece	90°	±2°



NOTES
1. The test piece is to have a surface roughness better than R*a* 5 μm except for the ends.
2. For machines with automatic positioning of the test piece the tolerance is to be taken as ±0,165 mm.

■ *Section 3* **Impact tests**

3.1 Dimensions of test specimens

3.1.1 Impact tests are to be of the Charpy V-notch type. The test specimens are to be machined to the dimensions and tolerances given in Table 2.3.1 and are to be carefully checked for dimensional accuracy.

3.1.2 For material under 10 mm in thickness, the largest possible size of standard subsidiary Charpy V-notch test specimen is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is less than 6 mm.

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines approved by Lloyd's Register (hereinafter referred as LR) and having a striking energy of not less than 150 J.

3.2.2 Charpy V-notch impact tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Chapters of these Rules. Where the test temperature is other than ambient, the temperature of the test specimen is to be controlled to within ±2°C for sufficient time to ensure uniformity throughout the cross-section of the test specimen, and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 18°C to 25°C.

3.2.3 For acceptance, the average energy value for a set of three impact tests must be equal to or greater than the appropriate specified minimum average value. Additionally, only one individual value may be less than the required average value but not less than 70 per cent of this average value.

3.2.4 Where standard subsidiary Charpy V-notch test specimens are necessary, the minimum energy values required are to be reduced as follows:
Specimen 10 x 7,5 mm: 5/6 of tabulated energy.
Specimen 10 x 5 mm: 2/3 of tabulated energy.

3.2.5 When reporting results, the specimen dimensions and the units used for expressing the energy absorbed (Joules) and the testing temperature are to be clearly stated.

■ *Section 4* Ductility tests for pipes and tubes

4.1 Bend tests

4.1.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1,6 mm.

4.1.2 Testing is to be carried out at ambient temperature, and the specimens are to be doubled over a former whose diameter is to be in accordance with the specific requirements for the material. For submerged arc welded tube the test piece is to be bent with the root of the weld in tension. For other tubes, the test piece is to be bent in the original direction of curvature. In all cases, the welds are to be in the middle of the test specimen. The test is considered to be satisfactory if, after bending, the specimens are free from cracks and laminations. Small cracks at the edges of the test specimens are to be disregarded.

4.2 Flattening tests

4.2.1 Ring test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The length of the specimen is to be equal to 1,5 times the external diameter of the pipe or tube, but is to be not less than 10 mm or greater than 100 mm. Alternatively, the length of the test specimen may be 40 mm irrespective of the external diameter.

4.2.2 Testing is to be carried out at ambient temperature and is to consist of flattening the specimens in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test specimen. Flattening is to be continued until the distance between the platens, measured under load, is not greater than the value given by the formula:

$$H = \frac{t\,(1 + C)}{C + \frac{t}{D}}$$

where
- H = distance between plates, in mm
- t = specified thickness of the pipe, in mm
- D = specified outside diameter, in mm
- C = a constant dependent on the steel type and detailed in the specific requirements

After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.

4.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

4.3 Drift expanding tests

4.3.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested may be rounded by filing.

4.3.2 For metallic tubes, the length of the specimen is to be at least 1,5 times the external diameter of the tube except when a mandrel with an included angle of 30° is used, in which case the length of the specimen is to be twice the external diameter of the tube. In all cases the length of section remaining cylindrical after test is not be less than 0,5 times the external diameter.

4.3.3 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of 30°, 45° or 60°, *see* Fig. 2.4.1. The mandrel is to be forced into the test specimen at a rate not exceeding 50 mm/min until the percentage increase in the outside diameter of the end of the test specimen is not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The expanded portion of the tube is to be free from cracks or other flaws.

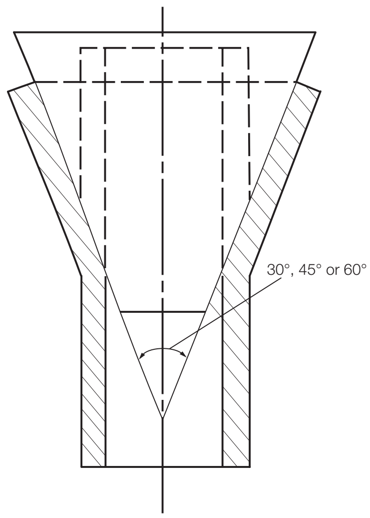


Fig. 2.4.1 Drift expanding test

4.4 Flanging tests

4.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The length of the specimens is to be at least equal to the external diameter of the tube and such that after testing the portion that remains cylindrical is not less than half the external diameter. The edges of the end to be tested may be rounded by filing.

4.4.2 Testing is to be carried out at ambient temperature and is to consist of flanging the end of the tube symmetrically by means of hardened conical steel mandrels. The rate of flanging is not to exceed 50 mm/min.

4.4.3 The first stage of flanging is to be carried out with a conical angled mandrel having an included angle of approximately 90°, *see* Fig. 2.4.2(a). The completion of the test is achieved with a second forming tool as shown in Fig. 2.4.2(b). The mandrels are to be lubricated and there is to be no rotation of the tube or mandrels during the test. The test is to continue until the drifted portion has formed a flange perpendicular to the axis of the test specimens. The percentage increase in the external diameter of the end of the specimens is to be not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The cylindrical and flanged portion of the tube is to be free from cracks or other flaws.

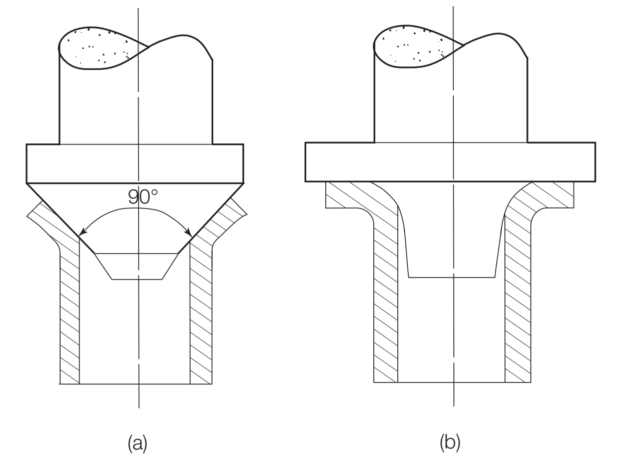


Fig. 2.4.2 Flanging test

Section 5
Embrittlement tests

5.1 Temper embrittlement tests

5.1.1 The test material is to be heat treated in accordance with the specification except that after tempering:
(a) half the material is to be water quenched;
(b) the other half is to be cooled from the tempering temperature to 300°C at a rate not exceeding 10°C per minute.

5.1.2 Impact tests in accordance with Section 3 are to be made on the material in each condition at temperatures over a range wide enough to establish the upper and lower shelf energies and temperatures, tests being made at no less than three intermediate temperatures.

5.1.3 A set of three specimens is to be tested at each temperature. The results are to be plotted separately for each condition, in the form illustrated in Fig. 2.5.1. In addition, the test temperatures, proportions of crystallinity and absorbed energies for all the specimens tested are to be reported.

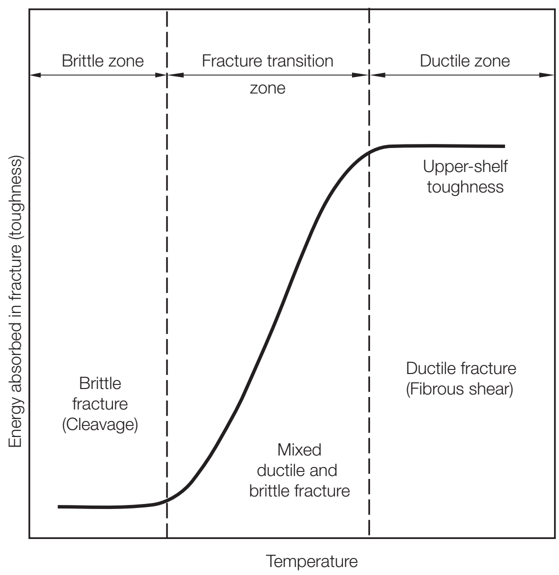


Fig. 2.5.1 Idealised transition curve

5.1.4 The transition temperature for each condition is to be taken as the mid-temperature of the fracture transition zone. The difference between the two transition temperatures is to be reported.

5.2 Strain age embrittlement tests

5.2.1 The test material is to be heat treated in accordance with the specification and then subjected to five per cent strain. Half of the test material is then to be heated to 250°C and held for one hour.

5.2.2 Impact tests in accordance with 5.1.2 are to be made in both the strained and unstrained conditions.

5.2.3 The tests are to comply with 5.1.3.

5.2.4 The test results are treated in accordance with 5.1.4.

5.3 Hydrogen embrittlement tests

5.3.1 Two specimens are to be tested. The specimens are to be of a diameter of 20 mm. Where this is not practicable a diameter of 14 mm may be accepted.

5.3.2 One specimen is to be tested within a maximum of 3 hours after machining. Where the specimen diameter is 14 mm, the time limit is 1,5 hours. Alternatively, the specimen may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of 5 days before being tested.

5.3.3 The other specimen is to be tested after baking at 250°C for 4 hours. Where the specimen diameter is 14 mm the baking time is to be 2 hours.

5.3.4 A strain rate not exceeding 0,0003s^{-1} is to be used during the entire test, until fracture occurs.

5.3.5 Tensile strength, elongation and reduction of area are to be reported.

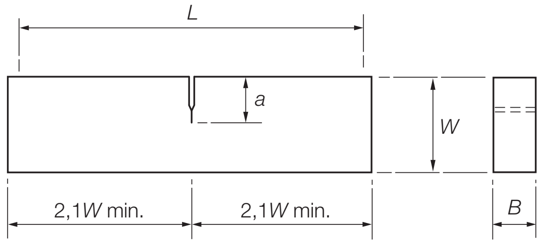
5.3.6 The ratio Z_1/Z_2 is to be reported, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

■ *Section 6* **Crack tip opening displacement tests**

6.1 Dimensions of test specimens

6.1.1 Unless agreed otherwise, tests are to be made on specimens of the full section thickness and which conform to a nationally agreed standard.

6.1.2 Normally the specimens are to be rectangular with the main dimensions as indicated in Fig. 2.6.1 and are to be tested in three point bending.

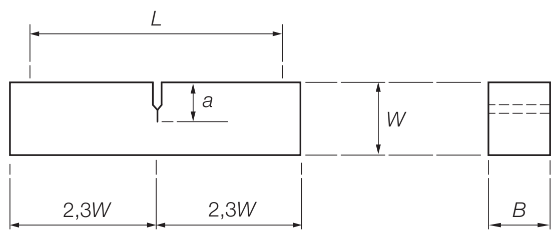


B = thickness
W = width = 2*B*
a = effective crack length = 0,45*W* to 0,55*W*
L = loading span = 4*W*

Fig. 2.6.1
Outline dimensions of the preferred specimen

6.1.3 A subsidiary specimen as in Fig. 2.6.2 may be used by agreement.

6.1.4 In each case the notch is to be positioned at the centre of the loading span; its root radius is not to exceed 0,10 mm. The notch is to be extended by the generation of a fatigue crack to give an effective crack length of the dimension *a*. For this purpose, the fatigue stress ratio, R_1, is to be within the range 0 to 0,1 and the fatigue intensity is not to exceed 0,63σ_γ $B^{1/2}$ where σ_γ is the 0,2 per cent proof stress at the test temperature.



B = thickness
W = width = *B*
a = effective crack length (to be agreed between the purchaser and manufacturer)
L = loading span = 4*W*

Fig. 2.6.2
Outline dimensions of the subsidiary specimen

6.2 Test equipment

6.2.1 Whenever possible, tests are to be made using machines operating under displacement control. The type of control is to be recorded.

6.2.2 The test equipment is to be calibrated annually.

6.2.3 The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

6.3 Testing procedures

6.3.1 Tests are to be made in a recognised test house in accordance with a nationally accepted standard.

6.3.2 Unless otherwise agreed, all tests on unwelded wrought material are to be made on specimens taken transverse to the principal working direction and are to be through-thickness notched.

6.3.3 Where tests are made on weld material, the fatigue crack should be arranged to sample the maximum amount of unrefined weld metal.

6.3.4 Where tests are made on the Heat Affected Zone (H.A.Z.) of a weld, a K or single bevel weld preparation is recommended. The region of lowest fracture toughness in the Heat Affected Zone should be identified for the particular steel and weld procedure by means of preliminary tests. The fatigue crack is to be accurately positioned to sample as high a proportion of this critical region as possible and after testing has been completed, the specimen is to be sectioned to check that this has been achieved. Sufficient tests should be made to ensure that the critical region has been sampled in at least three specimens.

6.3.5 At least three valid tests are to be made for each material condition. Invalid tests are to be disregarded and the tests repeated.

6.3.6 Local pre-compression of the test specimen ahead of the notch is acceptable in order to provide an acceptably even fatigue crack front.

6.3.7 The temperature of the test piece is to be measured to within ±2°C over the range minus 196°C to +200°C and to within ±5°C outside this range. The temperature should be measured at a point on the specimen not farther than 2 mm away from the crack tip.

6.4 Validity requirements

6.4.1 The test is to be regarded as invalid if:
(a) the fatigue crack front is not in a single plane;
(b) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch exceeds 10°;
(c) the length of any part of the fatigue crack is less than 0,025*W* or 1,25 mm, whichever is the greater;
(d) the difference between the maximum and minimum lengths of the fatigue crack exceeds 0,1*W*;
(e) the difference between any two of the lengths of the fatigue crack at 0,25*B*, 0,5*B* and 0,75*B* exceeds 0,05*W*.

6.4.2 In addition, for tests on welds and Heat Affected Zones (H.A.Z.), the following criteria are to be complied with:
(a) Weld metal. The fatigue crack front shall not extend outside the weld metal deposit and 80 per cent should be within 2 mm of the fusion line.
(b) Grain coarsened H.A.Z.. The fatigue crack should be within 0,5 mm of the fusion line and should sample all of the grain coarsened H.A.Z. present. However, if fusion line irregularities prevent this, a sample including as much grain coarsened H.A.Z. as possible may be accepted.
(c) Subcritical/intercritical H.A.Z. boundary. The fatigue crack is to sample the boundary between the subcritical and intercritical regions of the H.A.Z. However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

6.5 Test reports

6.5.1 The test report is to include:
(a) details of the material, its condition and size;
(b) the thickness and width of the test specimen;
(c) the fatigue pre-cracking conditions;
(d) the test temperature and environment;
(e) the test machine control system and rate of change of displacement or load;
(f) crack length measurements;
(g) force/displacement records, preferably in the form of an autographic record;
(h) the critical crack opening displacement;
(j) a photograph of the fracture;
(k) any observation on the fracture surface.

■ *Section 7* **Bend tests**

7.1 Dimensions of test specimens

7.1.1 Flat bend test specimens are to be of rectangular cross-section with dimensions as defined in Fig. 2.7.1.

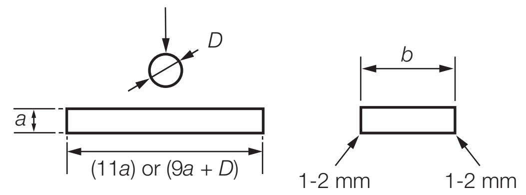


Fig. 2.7.1 Bend test specimen

7.1.2 For plates, sections and strip the dimensions shall be full thickness and width 30 mm. Where the rolled thickness exceeds 25 mm the compression face may be reduced to 25 mm.

7.1.3 For forgings, castings and semi-finished products the thickness shall be 20 mm and width 25 mm.

7.1.4 Butt weld face and root bend test specimens are to be 30 mm in width and of the full plate thickness. Where the thickness exceeds 25 mm, two side bend test specimens may be tested in place of the face and root specimens specified. The side bend specimens should be 10 mm minimum thickness. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

7.1.5 The edges on the tension side of bend samples are to be rounded to a radius of 1 to 2 mm.

7.2 Testing procedures

7.2.1 The bend sample is plastically deformed by plunging a mandrel between two fixed points as shown in Fig. 2.7.2.

7.2.2 For aluminium welds a guided bend is required to ensure even deformation as shown in Fig. 2.7.3.

7.2.3 Bend tests are to be conducted at ambient temperature at the highest convenient rate of bending (but not impact).

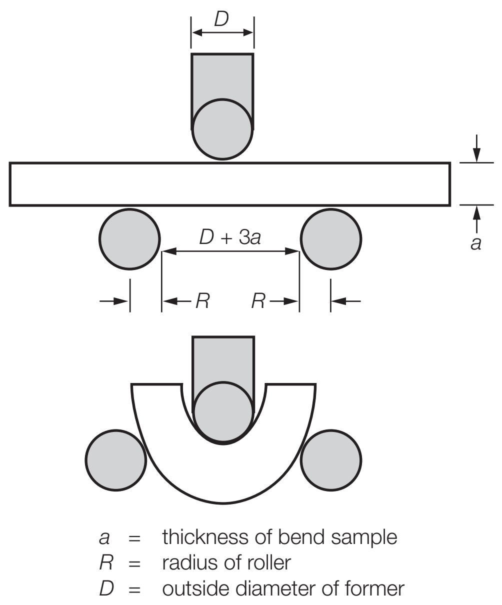


Fig. 2.7.2 Bend test

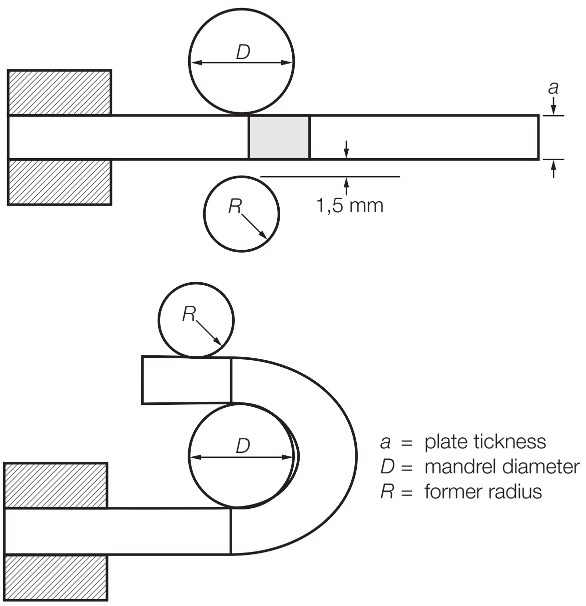


Fig. 2.7.3 Guide bend test for aluminium

■ *Section 8* Hardness testing

8.1 Dimensions of test specimens

8.1.1 Test pieces must be held rigidly in relation to the indenter and located such that the surface to be tested is at right angles to the axis of the indenter.

8.1.2 The surface finish of the test piece is to be such as to be able to measure the indent accurately.

8.2 Testing procedure

8.2.1 Hardness testing is to be carried out according to ISO 6506-1, ISO 6507-1 or equivalent for the type of hardness test.

■ *Section 9* Corrosion tests

9.1 Intergranular corrosion test

9.1.1 For all products other than pipes, the material for the test specimens is to be taken adjacent to that for the tensile test and is to be machined to suitable dimensions for either a round or rectangular section bend test. The diameter or thickness is to be not more than 12 mm, and the total surface area is to be between 1500 mm^2 and 3500 mm^2.

9.1.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases the total surface area is to be between 1500 mm^2 and 3500 mm^2.

9.1.3 Specimens are to be heated to a temperature of 700 ± 10ºC for 30 minutes, followed by rapid cooling in water. They are then to be placed on a bed of copper turnings (50 g per litre of test solution) and immersed for 15 to 24 hours in a boiling solution of the following composition:

- 100 g of hydrated copper sulphate granules ($CuSO_4.5H_2O$)
- 184 g (100 ml) sulphuric acid (density 1,84 g/ml) added dropwise to distilled water to make 1 litre of solution.

Precautions are to be taken during boiling to prevent concentration of the solution by evaporation.

9.1.4 After immersion, the full cross-section test specimens from pipes are to be subjected to a flattening test in accordance with Ch 2,4.2. All other test specimens are to be bent, at ambient temperature, through 90º over a former with a diameter equal to twice the diameter or thickness of the test specimen.

9.1.5 After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for hot rolled plates and sections intended for use in the construction of ships, other marine structures, machinery, boilers and pressure vessels.

1.1.2 This Chapter is not applicable to hot rolled bars intended for the manufacture of bolts, plain shafts, etc., by machining operations only. Where used for this purpose, hot rolled bars are to comply with the requirements of Chapter 5.

1.1.3 Plate and strip which is hot coiled after rolling and subsequently uncoiled, cold flattened and cut to the required dimensions are also subject to the appropriate requirements of this Chapter.

1.1.4 Plates, strip, sections and bars are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2 to 10.

1.1.5 As an alternative to 1.1.4, materials which comply with National or proprietary specifications may be accepted, provided that these specifications give equivalence to the requirements of this Chapter or are approved for a specific application. Particular attention is to be taken of the minimum required under thickness tolerance, *see* 1.6. Generally, survey and certification of such materials are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 Steels intended for high heat input welding above 50 kJ/cm are to be specially approved. Approval will be indicated on the manufacturer's approval certificate by adding a high heat input welding notation to the grade approved, e.g., EH36-W300, indicating approval up to 300 kJ/cm.

1.2 Steel with guaranteed through thickness properties – 'Z' grade steel

1.2.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, 'Z' grade steel. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration 'T'-butt welds, but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Requirements for 'Z' grade plate material are detailed in Section 8. It is the responsibility of the fabricator to make provision for the use of this material.

1.2.2 Steels intended to have guaranteed through thickness properties will include the supplementary suffix Z25 or Z35 in the designation, for example: LR DH36 Z35.

1.3 Corrosion resistant steels for cargo oil tanks of crude oil tankers

1.3.1 This sub-Section refers to normal and higher strength steels that have approved enhanced corrosion resistance properties intended for application in the internal cargo oil tanks of crude oil tankers.

1.3.2 The additional approval procedures for these steels include specific corrosion tests, *see* Ch 1,2.2.

1.3.3 Normal and higher strength corrosion resistant steels are to be manufactured, tested and certified in accordance with the applicable requirements of Section 2 or Section 3 and the requirements detailed in this sub-Section.

1.3.4 Corrosion resistant steels for cargo oil tanks are primarily intended to apply to steel plates, wide flats and sections up to 50 mm thick and to bars up to 50 mm in diameter.

1.3.5 Corrosion resistant steels for cargo oil tanks are to be identified with one of the following supplementary suffixes, RCU, RCB or RCW in the designation, for example, LR DH36 RCB. These suffixes relate to the area of the tank for which approval testing has been obtained:

RCU, for lower surface of strength deck and surrounding structures;
RCB, for upper surface of inner bottom plating and surrounding structures;
RCW, for both strength deck and inner bottom plating.

1.3.6 Corrosion resistant steels are not to be used in applications other than those specified in 1.3.1.

1.3.7 The weldability of corrosion resistant steels is similar to conventional normal and higher strength steels. Therefore the welding requirements specified in Chapters 11 to 13 are to be adhered with the exception that each corrosion resistant steel is approved with a specified brand of welding consumable and associated welding process.

1.3.8 Each manufacturer's approval certificate for corrosion resistant steels will state the steel grade and area of application designation, specified chemical composition range including additive and/or controlling element percentages to improve corrosion resistance, and brand of welding consumables and welding process used for approval.

1.4 Manufacture

1.4.1 All materials are to be manufactured at works which have been approved by Lloyd's Register (hereinafter referred to as 'LR') for the type and grade of steel which is being supplied and for the relevant steel-making and processing route.

1.4.2 Steel is to be cast in metal ingot moulds or by the continuous casting process. The size of the ingot, billet or slab is to be proportional to the dimensions of the final product such that the reduction ratio is normally to be at least 3 to 1. Sufficient discard is to be taken to ensure soundness in the portion used for further processing.

1.4.3 The cast analysis to be used for certification purposes is to be determined after all alloying additions have been carried out and sufficient time allowed for such an addition to homogenise.

1.4.4 Material may be supplied either as-rolled, normalised, normalising rolled, or thermomechanically controlled rolled. The following definitions apply:

(a) As-rolled (AR) refers to rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than those of steel heat treated, after rolling, or steel produced by advanced processes.

(b) Normalising (N) refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

(c) Normalising rolling (NR), also known as controlled rolling, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(d) Thermomechanically controlled rolling (TM) is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike normalising rolling the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM may also be accepted subject to the special approval by LR.

(e) Accelerated Cooling, (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other austenitising heat treatment.

(f) Quenching and Tempering (QT),is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.4.5 Where material is being produced by a normalising rolling or a thermomechanically controlled process (T.M.) an additional program of tests for approval is to be carried out under the supervision of the Surveyors and the results are to be to the satisfaction of LR.

1.4.6 Weldable high strength steels may be supplied in the quenched and tempered condition for other marine structures, *see* Section 10.

1.5 Quality of materials

1.5.1 Surface and internal imperfections not prejudicial to the proper application of the steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with an appropriate acceptance standard, is to be agreed between the purchaser, steelmaker and Surveyor and is to be included in the manufacturing specification.

1.6 Dimensional tolerances

1.6.1 The tolerances on thickness of a given product are defined as:

(a) Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

(b) Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

Nominal thickness is defined by the purchaser at the time of enquiry and order.

1.6.2 The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements in 1.6.11.

1.6.3 For materials of nominal thickness 5 mm and more intended for hull structural purposes as detailed in Sections 2, 3 and 10, the minus tolerance on thickness of plates, strip and wide flats is 0,3 mm, irrespective of nominal thickness. For wide flats, this applies only where the width is greater than or equal to 600 mm. The average thickness of a product or products is not to be less than the nominal thickness. For thicknesses below 5 mm, the thickness tolerances are to be specially agreed. Plus tolerance is to be in accordance with a National or International Standard.

1.6.4 Class C of ISO 7452 may be applied in lieu of 1.6.3. Where this standard is applied, both the requirements in 1.6.11 and the portion of the footnote of Table B.2 in ISO 7542, that reads; 'Also a minus side of thickness of 0,3 mm is permitted,' are not applicable. Additionally, if ISO 7452 is applied, the steel mill is to ensure that the number of measurements and measurement distribution is appropriate to establish that the plates produced are greater than or equal to the specified nominal thickness.

1.6.5 The minus tolerance on bars and sections (except for wide flats with a width $\geq$ 600 mm) is to be in accordance with the requirements of a recognised National or International Standard.

1.6.6 The Shipbuilder and Owner may agree in individual cases whether they wish to specify a more stringent minus tolerance than that given in this Chapter.

1.6.7 The minus tolerances for plates and wide flats intended for machinery structures are given in Section 5.

1.6.8 For materials intended for applications as detailed in Sections 4 and 6, no minus tolerance is permitted in the thickness of plates and strip. The minus tolerances on sections are to comply with the requirements of a recognised National or International Standard.

1.6.9 For the materials detailed in Section 7, the minus tolerance of material intended for use in the construction of cargo tanks is not to exceed 0,3 mm. For other applications, no minus tolerance is permitted in the thickness of plates and strip.

1.6.10 Dimensional tolerances for material detailed in Section 9 are given in Table 3.9.3.

1.6.11 The average thickness and thickness tolerance is to be measured at locations of a product or products as defined below:

(a) An automated method or manual method may be applied to the thickness measurements. The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.
(b) At least two lines among Line 1, Line 2 or Line 3, as shown in Fig. 3.1.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Fig. 3.1.1 are to be selected for thickness measurement on each piece rolled from a single slab or ingot. If more than three points are taken on each line, then the number of points shall be equal on each line.

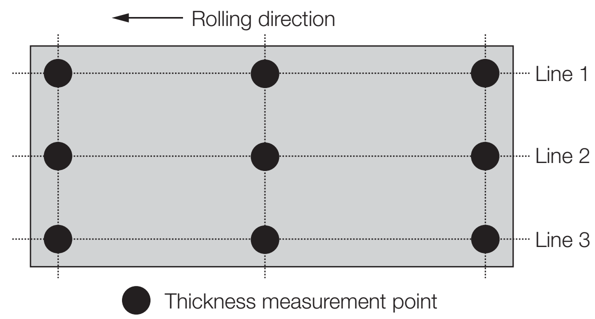


Fig. 3.1.1 Location of thickness measuring points

(c) For automated methods, the measuring points at sides are to be located not less than 10 mm but not greater than 300 mm from the transverse or longitudinal edges of the product.
(d) For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.
(e) Additional measurements may be requested by the Surveyor.

1.6.12 Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a recognised National or International Standard.

1.6.13 Tolerances relating to length, width, flatness and plus thickness are to comply with a National or International Standard.

1.6.14 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

1.6.15 The Shipbuilder is responsible for the storage and maintenance of product(s) delivered with acceptable surface conditions.

1.7 Heat treatment

1.7.1 Acceptable conditions of supply are specified in subsequent Sections of this Chapter.

1.7.2 The manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The Surveyor is to be advised of any heat treatment proposed.

1.7.3 Where material is manufactured using a thermo-mechanically controlled process consideration must be given to the possibility of consequent reduction in mechanical properties if it is subjected to heating for forming or stress relieving or is welded using a high heat input.

1.8 Test material and mechanical tests

1.8.1 Depending on the type of product, provision is made in subsequent Sections of this Chapter for the testing of individual items or for batch testing. Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form, (e.g., plates, flats, sections, etc.), from the same cast and in the same condition of supply.

1.8.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed. The test specimens are not to be separately heat treated in any way.

1.8.3 The test material is to be taken from the thickest piece in each batch, *see* Ch 1,4.1.

1.8.4 Test material is to be taken from the following positions:

(a) At the square cut end of plates and flats greater than 600 mm wide, approximately one-quarter width from an edge, *see* Fig. 3.1.2(a).

(b) For flats 600 mm or less in width, bulb flats and other solid sections, at approximately one-third of the width from an edge, *see* Fig. 3.1.2(b), (c) and (d). Alternatively, in the case of channels, beams or bulb angles, at approximately one-quarter of the width from the centreline of the web, *see* Fig. 3.1.2(c).

(c) For rectangular hollow sections, at approximately the centre of any side, *see* Fig. 3.1.2(e). For circular hollow sections, at any position on the periphery.

(d) For bars intended for purposes as detailed in Sections 2, 3, 5 and 9, at approximately one-third of the radius or half-diagonal from the outer surface, *see* Fig. 3.1.2(f). For smaller bars, the position of the test material is to be as close as is possible to the above.

(e) For bars intended for the applications detailed in Sections 4, 6 and 7 at approximately 12,5 mm below the surface. For bars up to 25 mm diameter, the test specimens may be machined coaxially.

(f) For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 3.1.2(g).

1.8.5 Tensile test specimens and impact test specimens, where required for the type and grade of product being supplied, are to be prepared from each item or batch of material submitted for acceptance.

1.8.6 Where the finished width of plates and flats is greater than 600 mm, the tensile test specimens are to be cut with their principal axes perpendicular to the final direction of rolling. For all other rolled products, the principal axes are to be parallel to the final direction of rolling.

1.8.7 The tensile test specimens are to be machined to the dimensions detailed in Ch 2,2.1.6 and 2.1.7.

1.8.8 Impact test specimens are to be cut with their principal axes either parallel (longitudinal test) or perpendicular (transverse test) to the final direction of rolling, as required by subsequent Sections of this Chapter. Where both longitudinal and transverse impact properties are shown for a particular grade, only the longitudinal test is required to be carried out, unless otherwise specified by the purchase order or subsequent Sections of this Chapter. However, for plates and wide flats, by certifying that the product meets the requirements of the Rules, the manufacturer guarantees that the acceptance values will be met if tested in the transverse direction. The Surveyor may request testing in this direction to confirm conformity.

1.8.9 Impact test specimens are to be of the Charpy V-notch type, machined to the dimensions detailed in Chapter 2. They are to be taken from a position within 2 mm of one of the rolled surfaces, except that for plates and sections over 40 mm thick, the axes of the test specimens are to be at one-quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axes of the test specimens are to be as specified in 1.8.4(d).

1.8.10 Standard test specimens 10 mm square are to be used, except where the thickness of the material does not allow this size of test specimen to be prepared. In such cases the largest possible size of subsidiary test specimen, in accordance with Table 2.3.1 is to be prepared, with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test specimen width will be the full thickness of the material. In such cases the tolerances for width given in Table 2.3.1 in Chapter 2 are not applicable. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

1.8.11 Impact tests are not required when the nominal material thickness is less than 6 mm.

1.8.12 The test procedures used for all tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.9 Visual and non-destructive examination

1.9.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

1.9.2 With the exception of 'Z' grade plate material (*see* Section 8) and bars for offshore mooring cable (*see* Section 9), the non-destructive examination of materials is not required for acceptance purposes, *see also* 1.5.1. However, manufacturers are expected to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

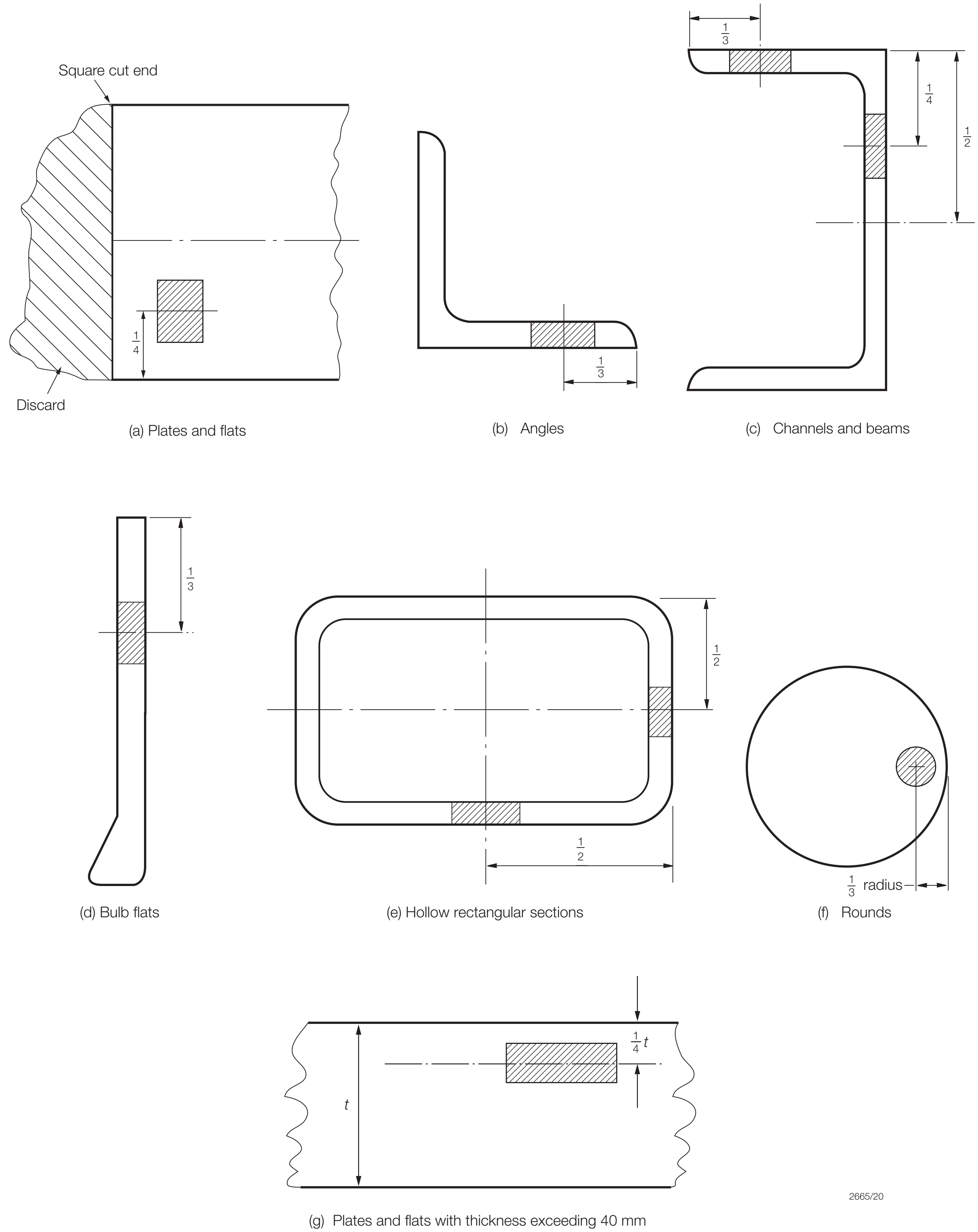


Fig. 3.1.2 Position of test material

1.10 Rectification of defects

1.10.1 For materials intended for structural purposes as detailed in Sections 2, 3 and 5, surface defects may be removed by local grinding provided that:

(a) the thickness is in no place reduced to less than 93 per cent of the nominal thickness, but in no case by more than 3 mm,
(b) each single ground area does not exceed 0,25 m^2,
(c) the total area of local grinding does not exceed two per cent of the total surface,
(d) the ground areas have smooth transitions to the surrounding surface.

Where necessary, the entire surface may be ground to a maximum depth as given by the underthickness tolerances of the product. The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed. They may request that complete removal of the defect is proven by suitable non-destructive examination of the affected area.

1.10.2 Surface defects which cannot be dealt with as in 1.10.1 may be repaired by chipping or grinding followed by welding, subject to the Surveyor's consent and under his supervision, provided that:

(a) after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,
(b) each single weld does not exceed 0,125 m^2,
(c) the total area of welding does not exceed two per cent of the surface of the side involved,
(d) the distance between any two welds is not less than their average width,
(e) the welds are of reasonable size and made with an excess layer of beads which is then ground smooth to the surface level,
(f) elimination of the defect is proven by suitable non-destructive examination of the affected area,
(g) welding is carried out by an approved procedure and by competent operators using approved electrodes and the repaired area is ground smooth to the correct nominal thickness,
(h) when requested by the Surveyor, the item is normalised or otherwise suitably heat treated after welding and grinding, and
(j) at the discretion of the Surveyor, the repaired area is proven free from defects by suitable non-destructive examination.

1.10.3 For materials intended for applications as detailed in Sections 4, 6 and 7, surface defects may be removed by grinding in accordance with 1.10.1, except that when the thickness is reduced below that given in the approved plans, acceptance will be subject to special consideration. Weld repairs may also be carried out generally in accordance with 1.10.2, except that in all cases suitable heat treatment after welding and non-destructive testing of the repaired areas is required. The fabricator is to be advised regarding the position and extent of all repairs.

1.10.4 For plates which have been produced by a T.M. process or by normalising rolling, repair by welding will be approved by the Surveyor only after procedure tests have shown that the mechanical properties have not been impaired.

1.10.5 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

1.11 Identification of materials

1.11.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand and the following particulars:

(a) The manufacturer's name or trade mark.
(b) The grade of steel. The designations given in subsequent Sections of this Chapter may be preceded by the letters 'LR' in order to fully describe the grade, e.g. LR A, LR 490FG. LR LT-FH40, LR 316L, etc.
(c) When the material complies with the requirements of Section 8, the grade is to include the suffix Z25 or Z35, e.g., LR AH36 Z35.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

1.11.2 Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.11.3 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.8.

1.12 Certification of materials

1.12.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and is to include the following particulars:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is dispatched.
(d) Name of steelworks.
(e) Description and dimensions of the material.
(f) Specification or grade of the steel.
(g) Identification number of piece, including test specimen number where appropriate.
(h) Cast number and chemical composition of ladle samples.

(j) Mechanical test results (not required on shipping statements).
(k) Condition of supply.

1.12.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

> 'We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register'.

1.12.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the steel was produced must be approved by LR.

1.12.4 The manufacturer of coiled plate is required to issue a certificate which clearly identifies the material as coil. The certificate issued should include the words; 'Coils covered by this certificate require further processing at a works approved by Lloyd's Register before being certified as plate in accordance with the Rules of Lloyd's Register' in addition to the requirements of 1.12.2.

1.12.5 The supplier of plate cut from coil is required to issue a certificate which clearly identifies the product as finished plate meeting the requirements of the Rules in accordance with 1.12.2.

1.12.6 The form of certificates produced by computer systems is to be agreed with the Surveyor.

■ *Section 2*
Normal strength steels for ship and other structural applications

2.1 Scope

2.1.1 The requirements of this Section are primarily intended to apply to steel plates and wide flats not exceeding 100 mm in thickness and sections and bars not exceeding 50 mm in thickness in Grades A, B, D and E. For greater thicknesses, variations in the requirements may be permitted or required for particular applications.

2.1.2 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 mm in thickness.

2.2 Manufacture and chemical composition

2.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 3.2.1.

2.2.2 Small variations from the chemical compositions given in Table 3.2.1 may be allowed for Grade E steel in thicknesses exceeding 50 mm or when any Grade of steel is supplied in a thermo-mechanically controlled processed condition, provided that these variations are documented and approved in advance.

2.2.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyors.

2.2.4 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

2.3 Condition of supply

2.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.2.2. Where alternative conditions are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material, but a steelmaker is to supply materials only in those conditions for which he has been approved by LR.

2.3.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

2.3.3 If a steel product supplied in the T.M. condition is to be subjected to heating for forming or stress relieving or is to be welded by a high energy input process, consideration must be given to the possibility of a consequent reduction in mechanical properties.

2.4 Mechanical tests

2.4.1 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3 except where enhanced by the requirements of this Section.

Table 3.2.1 Chemical composition and deoxidation practice

Grade	A	B	D	E
Deoxidation	For $t \le 50$ mm: Any method (for rimmed steel, *see* Note 1)	For $t \le 50$ mm: Any method except rimmed steel	For $t \le 25$ mm: Killed	Killed and fine grain treated with aluminium
	For $t > 50$ mm: Killed	For $t > 50$ mm: Killed	For $t > 25$ mm: Killed and fine grain treated with aluminium	
Chemical composition % (*see* Note 5)				
Carbon	0,21 max. (*see* Note 2)	0,21 max.	0,21 max.	0,18 max.
Manganese	2,5 x C% min.	0,80 min. (*see* Note 3)	0,60 min.	0,70 min.
Silicon	0,50 max.	0,35 max.	0,10 – 0,35	0,10 – 0,35
Sulphur	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Phosphorus	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Aluminium (acid soluble)	—	—	0,015 min. (*see* Note 4)	0,015 min. (*see* Note 4)
	Carbon + $^1/_6$ of the manganese content is not to exceed 0,40%			

NOTES
1. For Grade A, rimmed steel may only be accepted for sections up to a maximum thickness of 12,5 mm, provided that it is stated on the test certificates or shipping statements to be rimmed steel.
2. The maximum carbon content for Grade A steel may be increased to 0,23% for sections.
3. Where Grade B is impact tested the minimum manganese content may be reduced to 0,60%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. Where additions of any other elements are made as part of the steel-making practice, the content is to be recorded.

Table 3.2.2 Condition of supply

Grade	Thickness, mm	Conditions of supply			
A and B	≤50	Any			(*see* Note 1)
	>50 ≤100	N	NR	TM	(*see* Note 2)
D	≤35	Any			(*see* Note 1)
	>35 ≤100	N	NR	TM	(*see* Note 3)
E	≤100	N		TM	(*see* Note 4)

N = normalised
NR = normalising rolled
TM = thermomechanically controlled-rolled

NOTES
1. ‘Any’ includes as-rolled, normalised, normalising rolled and thermomechanically controlled-rolled.
2. Plates, wide flats, sections and bars may be supplied in the as-rolled condition, subject to special approval from LR.
3. Sections in Grade D steel may be supplied in thicknesses greater than 35 mm in the as-rolled condition provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Sections in Grade E steel may be supplied in the as-rolled and normalising rolled conditions provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.

2.4.2 With the exception given in 2.4.4, one tensile test is to be made for each batch presented unless the mass of finished material is greater than 50 tonnes, in which case one test is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates, strip, sections or bars.

2.4.3 For Grades A and B where plate is supplied from coil, results of the tensile test can be transposed from the certificate of the coil manufacture onto the certificate issued by the re-processor. If the coil mass exceeds 50 tonnes, testing will additionally be required from two locations representing the start and end of the coil. For Grades D and E, the mechanical properties must be sampled from the de-coiled plate in accordance with the frequency specified in the Rules.

2.4.4 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on $5,65\sqrt{S_o}$ % minimum	Charpy V-notch impact test (*see* Notes 3, 4, 5, 6 and 7)		
				Thickness mm	Average energy J minimum	
					Longitudinal	Transverse (*see* Note 3)
A B D E	235	400 – 520 (*see* Note 1)	22 (*see* Note 2)	≤50 >50 ≤70 >70 ≤100	27 34 41	20 24 27

Impact tests are to be made on the various grades at the following temperatures:

A grade	not required
B grade	0°C
D grade	–20°C
E grade	–40°C

NOTES

1. For sections in Grade A, the upper limit of the tensile strength range may be exceeded at the discretion of the Surveyor.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2), the minimum elongation is to be:

Thickness mm	≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤35	>35 ≤50
Elongation %	14	16	17	18	19	20	21	22

3. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be garenteed by the supplier.
4. *See* 2.4.5 and 2.4.6.
5. *See* 2.4.7.
6. *See* 1.8.11.
7. *See* 2.4.14.

2.4.5 For Grade A steel, Charpy V-notch impact tests are not required when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalised or thermo-mechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

2.4.6 When Grade A steel is supplied in a thickness greater than 50 mm and either, in the normalising rolled condition, or when special approval has been given to supply in the as-rolled condition, a set of three impact test specimens is to be tested from each batch of 50 tonnes or fraction thereof.

2.4.7 Impact tests are not required for Grade B steel of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement in Table 3.2.3. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

2.4.8 For Grade B steels of thicknesses above 25 mm, supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.9 For Grade B steels of thicknesses above 25 mm, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.10 For Grade D steels supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.11 For Grade D steels, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.12 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece. For bars and sections in Grade E steel, one set of three test specimens is to be made from each 25 tonnes or fraction thereof. When, subject to the special approval of LR, sections are supplied in the as-rolled or normalising rolled conditions, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

2.4.13 The results of all tensile tests and the average energy values from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

2.4.14 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalised, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.2.3. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 2.3.2.

2.4.15 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

2.5 Identification of materials

2.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted. Where a number of light materials are bundled, the bundle is to be identified in accordance with 1.11.2.

2.6 Certification of materials

2.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. As a minimum, the chemical composition is to include the contents of any grain refining elements used and the residual elements, as detailed in Table 3.2.1.

■ *Section 3* Higher strength steels for ship and other structural applications

3.1 Scope

3.1.1 Provision is made for material to be supplied in four strength levels, 27S, 32, 36 and 40.

3.1.2 Provisions for material supplied in H47 strength grades are specifically intended for hatch comings and deck structure of container ships.

3.1.3 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

3.1.4 For the designation to fully identify a steel and its properties the appropriate grade letters should precede the strength level number, e.g. AH32 or FH40.

3.1.5 The requirements of this Section are primarily intended to apply to plates, wide flats, sections and bars not exceeding the thickness limits given in Table 3.3.1. For greater thicknesses, variations in the requirements may be permitted or required for particular applications but a reduction of the required impact energy is not allowed.

Table 3.3.1 Maximum thickness limits

Steel designation				Maximum thickness mm	
				Plates and wide flats	Sections and bars
AH 27S	DH 27S	EH 27S	FH27S	100 (see Note 1)	50
AH 32	DH 32	EH 32	FH32		
AH 36	DH 36	EH 36	FH36		
AH 40	DH 40	EH40	FH40		
(*see* Note 2)		EH 47			Not applicable

NOTES
1. Where the thickness exceeds 50 mm, the steel must initially be approved by way of a Nil Ductility Test, in accordance with ASTM E208, to show adequate crack arrest properties. The Nil Ductility Test Temperature is to be agreed for the thickness approved to ensure the crack arrest temperature is below the minimum design temperature. Where the thickness exceeds 70 mm and the material is used specifically as a crack arrest plate, the material must be specially approved with a crack arrest fracture toughness Kca ≥ 6000 N/mm^{1,5}.
2. Minimum thickness for H47 strength level is 50 mm, *see* 3.1.2.

3.1.6 It should be noted that the fatigue strength of weldments in steels of high strength levels may not be greater than those of steels of lower strength levels.

3.2 Alternative specifications

3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see* 3.7.2.

3.3 Manufacture

3.3.1 All the grades of steel are to be in the killed and fine grain treated condition.

3.4 Chemical composition

3.4.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements given in Table 3.3.2. The requirements for H47 strength grade steels are given in Table 3.3.3.

3.4.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

For TM steels, the agreed carbon equivalent is not to exceed the values given in Table 3.3.4.

3.4.3 The cold cracking susceptibility, P_{cm}, may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used for calculating the P_{cm} from the ladle analysis:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate.

3.4.4 The cold cracking susceptibility, P_{cm}, is to have a maximum value of 0,22 per cent for steels of H47 strength grade.

3.4.5 Small deviations in chemical composition from that given in Table 3.3.2 for plates exceeding 50 mm in thickness in Grades EH36, EH40, FH36 and FH40 may be approved provided that these deviations are documented and approved in advance.

3.4.6 Where the grain refining elements Niobium, Titanium and Vanadium are used either singly or in combination, the chemical composition is to be specifically approved for each Grade in combination with the rolling procedure to be used.

Table 3.3.2 Chemical composition

Grades	AH, DH, EH	FH
Carbon % max.	0,18	0,16
Manganese %	0,9 – 1,60 (*see* Note 1)	0,9 – 1,60
Silicon % max.	0,50	0,50
Phosphorus % max.	0,035	0,025
Sulphur % max.	0,035	0,025
Grain refining elements (*see* Note 2)		
Aluminium (acid soluble) %	0,015 min. (*see* Note 3)	
Niobium %	0,02 – 0,05	
Vanadium %	0,05 – 0,10	
Titanium %	0,02 max.	
Total (Nb + V + Ti) % (*see* Note 5)	0,12 max.	
Residual elements		
Nickel % max.	0,40	0,80
Copper % max.	0,35	0,35
Chromium % max.	0,20	0,20
Molybdenum % max.	0,08	0,08
Nitrogen % max.		0,009 (0,012 max. if Al is present)

NOTES
1. For AH grade steels in all strength levels and thicknesses up to 12,5 mm, the specified minimum manganese content is 0,70%.
2. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
4. Alloying elements other than those listed above are to be included in the approved manufacturing specification.
5. The grain refining elements are to be in accordance with the approved specification.

Table 3.3.3 Chemical composition for Grade EH 47

Chemical element	max. (%)
Carbon	0,20
Manganese	2,00
Silicon	0,55
Phosphorus	0,030
Sulphur	0,030
Nickel	2,00
Chromium	0,25
Molybdenum	0,080
Grain refining elements (*see* Note 1) Aluminium (acid soluble)	0,015 min (*see* Note 2)
Residual elements Copper 0,35	

NOTES
1. The grain refining elements niobium, vanadium and titanium are to be in accordance with the approved specification.
2. The total aluminium content may be determined instead of the acid soluble content. In these cases the total aluminium content is to be not less than 0,020%.

3.4.7 When any grade is supplied in an approved thermomechanically controlled processed condition, variations in the specified chemical composition may be considered, provided that these variations are documented and approved in advance.

3.4.8 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.3.5 or Table 3.3.6. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

3.5.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

3.5.3 The use of precipitation hardening steels is not acceptable, except where such hardening is incidental to the use of grain refining elements.

3.6 Mechanical tests

3.6.1 The results of all tensile tests and the average energy value from each set of three Charpy V-notch impact tests are to comply with the appropriate requirements given in Table 3.3.7 except where enhanced by the requirements of this Section.

3.6.2 For steels in the as-rolled, normalised, normalising rolled or T.M. conditions, one tensile test is to be made for each batch of 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

3.6.3 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

3.6.4 For steels in the quenched and tempered condition a tensile test is to be made on each plate as heat treated. For continuously heat treated plates, one tensile test is to be made for each 50 tonnes or fraction thereof from a single cast. Additional tests are to be made for every variation of 10 mm in the thickness of the products from a single cast. The tensile test specimens are to be taken with their axes transverse to the main direction of rolling.

Table 3.3.4 Carbon equivalent requirements for higher tensile strength steels up to 100 mm in thickness when supplied in the TM condition

Grade				Carbon Equivalent, max. (%)	
				$t \leq 50$	$50 < t \leq 100$
AH 27S	DH 27S	EH 27S	FH 27S	0,36	0,38
AH 32	DH 32	EH 32	FH 32	0,36	0,38
AH 36	DH 36	EH 36	FH 36	0,38	0,40
AH 40	DH 40	EH 40	FH 40	0,40	0,42
		EH 47		Not applicable (*see* Table 3.3.1)	0,49

NOTE
t = thickness, in mm.

Table 3.3.5 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 27S AH 32 AH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
AH 40	Any practice	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
DH 27S DH 32 DH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
DH 40	Any practice	≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
EH 27S EH 32 EH 36	Any practice	≤ 100	—	N	—	TM	
EH 40	Any practice	≤ 100	—	N	—	TM	QT
FH 27S FH 32 FH 36 FH 40	Any practice	≤ 100	—	N	—	TM	QT
EH 47	Any practice	≤ 50	Not applicable				
		>50 ≤100	—	—	—	TM	QT

NOTES
1. Grain refining elements used singly or in any combination, require specific approval from Materials and NDE Department, London office.
2. AR = as-rolled N = furnace normalised NR = normalising rolled
   TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Material up to 35 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.
4. Material up to 25 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.

3.6.5 For products in the AH and DH grades, at least one set of three impact tests is to be made on the thickest piece in each batch of 50 tonnes when supplied in either the normalised or thermomechanically controlled condition. When the products are supplied in the as-rolled or normalising rolled conditions a set of impact test specimens is to be taken from a different piece from each 25 tonnes or fraction thereof. When supplied in the quenched and tempered condition, a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.6 For plates and wide flats in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on each piece. For plates supplied in the quenched and tempered condition a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.7 For plates and wide flats in H47 strength grade, one set of impact tests is to be made on each piece.

3.6.8 For sections and bars in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on the thickest piece in a batch not exceeding 25 tonnes. For sections supplied in the as-rolled or normalising rolled conditions the batch size is not to exceed 15 tonnes.

Table 3.3.6 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)			
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
AH 40	Any practice	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
DH 40	Any practice	≤50	N	NR	TM	
EH 27S EH 32 EH 36	Any practice	≤50	N	TM		(*see* Notes 3 and 4)
EH 40	Any practice	≤50	N	TM	QT	
FH 27S FH 32 FH 36 FH 40	Any practice	≤50	N	TM	QT	(*see* Note 4)

NOTES
1. Grain refining elements used singly or in any combination require specific approval from Materials and NDE Department, London Office.
2. N = furnace normalised; NR = normalising rolled; TM = thermomechanically controlled-rolled; QT = quenched and tempered
3. Subject to the special approval of LR, sections may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Subject to the special approval of LR, sections may be supplied in the NR condition.

3.6.9 For batch tested plates in a condition other than furnace normalised, with a thickness equal to 12 mm or greater, and where the average value of one set of tests is less than 50 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 50 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.3.7. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 3.5.2.

3.6.10 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

3.7 Identification of materials

3.7.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint. Where a number of light products are bundled, the bundle is to be identified in accordance with 1.11.2.

3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter 'S' after the agreed identification mark.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, the chemical composition is to include the contents of any grain refining elements used and of the residual elements.

3.8.2 For steels which have been specially approved, the agreed identification mark, the specified minimum yield stress and, if applicable, the contents of alloying elements are additionally to be stated on the test certificate or shipping statement.

3.8.3 The steelmaker is to provide the Surveyor with a written declaration as detailed in 1.12.2.

Table 3.3.7 Mechanical properties for acceptance purposes (*see* Note 1) (*continued*)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 3, 4 and 5)					
				Average energy J minimum					
				$t \leq 50$ mm		$50 < t \leq 70$ mm		$70 < t \leq 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 27S DH 27S EH 27S FH 27S	265	400 – 530	22	27	20	34	24	41	27
AH 32 DH 32 EH 32 FH 32	315	440 – 570	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – 630	21	34	24	41	27	50	34
AH 40 DH 40 EH 40 FH 40	390	510 – 650	20	39	26	46	31	55 (*see* Note 8)	37 (*see* Note 8)
EH 47	460	570 – 720	17	–	–	53	35	64 (*see* Note 8)	42 (*see* Note 8)

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades –20°C
EH grades –40°C
FH grades –60°C

Table 3.3.7 Mechanical properties for acceptance purposes (*conclusion*)

NOTES
1. The requirements for products thicker than those detailed in the table are subject to agreement, *see* 3.1.4.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm, *see* Fig. 2.2.4 in Chapter 2, the minimum elongation is to be:

Thickness mm		≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤40	>40 ≤50	>50
Elongation %	Strength levels 27S, 32	14	16	17	18	19	20	21	22	To be specially agreed
	Strength level 36	13	15	16	17	18	19	20	21	
	Strength level 40	12	14	15	16	17	18	19	20	

3. Subject to special approval by LR, the minimum tensile strength may be reduced to 470 N/mm^2, for grades AH36, DH36, EH36 and FH36, in the TM condition when micro-alloying elements Nb, Ti or V are used singly and not in combination and provided the yield to tensile strength ratio does not exceed 0,89. For plates with a thickness ≤12 mm, the yield to tensile strength ratio is to be specially considered.
4. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.
5. *See* 1.8.11
6. *See* 3.6.9.
7. For steel of H47 strength grade, the yield to tensile strength ratio is not to exceed 0,94.
8. The Charpy V-notch impact energy for crack arrest steels of grade EH40, FH40 and EH47 intended for longitudinal strength members in container ships in thickness between 85 mm and 100 mm are to be:

Grade	85 < *t* ≤ 100 mm	
	Longitudinal	Transverse
AH40 DH40 EH40 FH40 EH47	75 J	50 J

■ Section 4 Steels for boilers and pressure vessels

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

4.1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

4.1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 N/mm^2 may be accepted, provided that details of the proposed specification are submitted for approval.

4.1.4 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 N/mm^2.

4.1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels storage tanks for liquefied gases and for other low temperature applications are to comply with the requirements of Section 6 or 7, as appropriate.

4.2 Manufacture and chemical composition

4.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements of Table 3.4.1.

Table 3.4.1 Chemical composition and deoxidation practice

Grade of steel	Deoxidation	Chemical composition %						
Carbon and carbon-manganese steels		C max.	Si	Mn	P	S	Al	Residual elements
360 AR	Any method except rimmed steel	0,18	0,50 max.	0,40 – 1,20	0,040 max.		–	Cr 0,25 max. Cu 0,30 max. Mo 0,10 max. Ni 0,30 max. Total 0,70 max.
410 AR		0,21		0,40 – 1,30			–	
460 AR		0,23		0,80 – 1,50			–	
360	Any method except rimmed steel	0,17	0,35 max.	0,40 – 1,20	0,035 max.		–	
410		0,20		0,50 – 1,30			–	
460		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,40			–	
490	Killed		0,10 – 0,50	0,90 – 1,60			–	
360 FG	Killed fine grained	0,17	0,35 max.	0,40 – 1,20	0,035 max.		(*see* Note 2)	
410 FG		0,20		0,50 – 1,30				
460 FG		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,50				
490 FG			0,10 – 0,50	0,90 – 1,60				
510 FG		0,22						

Alloy steel		C	Si	Mn	P S	Al	Cr	Mo	Residual elements
13Cr Mo 45	Killed	0,10–0,18	0,15–0,35	0,4–0,8	0,035 max.	(*see* Note 3)	0,70–1,30	0,40–0,60	Cu 0,30 max.
11Cr Mo 910		0,08–0,18	0,15–0,50				2,00–2,50	0,90–1,10	Ni 0,30 max.

NOTES
1. For thicknesses greater than 30 mm, carbon 0,22% max.
2. Aluminium (acid soluble) 0,015% min. or
Aluminium (total) 0,018% min.
Niobium, vanadium or other suitable grain refining elements may be used either in place of or in addition to aluminium.
3. Aluminium (acid soluble or total) 0,020% max.

4.2.2 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

4.3 Heat treatment

4.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.4.2 except that, when agreed, material intended for hot forming may be supplied in the as-rolled condition.

Table 3.4.2 Condition of supply

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As-rolled Maximum thickness or diameter is 40 mm
Carbon and carbon-manganese 360 to 490	Normalised or normalised rolled
Carbon and carbon-manganese 360 FG to 510 FG	Normalised or normalised rolled
13Cr Mo 45	Normalised and tempered
11Cr Mo 910	Normalised and tempered

4.4 Mechanical tests

4.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

4.4.2 For strip, tensile test specimens are to be taken from both ends of each coil.

4.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

4.4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steelworks are to be made on material which has been cut from the plates and given a normalising and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.4.5 If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Tables 3.4.3 to 3.4.5.

Table 3.4.3 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – As-rolled

Grade of steel	Thickness mm	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_0}$ % minimum
360 AR	≤ 40	190	360–480	24
410 AR		215	410–530	22
460 AR		240	460–580	21

4.4.7 Where plate is supplied from coil, the tensile tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

4.4.8 All test specimens are to be taken in the transverse direction unless otherwise agreed.

4.4.9 When material will be subject to strains in a through thickness direction, it is recommended that it should have specified through thickness properties in accordance with the requirements of Section 8.

4.5 Identification of materials

4.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

4.6 Certification of materials

4.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and to give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the content of any grain refining elements used and of the residual elements, as detailed in Table 3.4.1.

4.7 Mechanical properties for design purposes

4.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Tables 3.4.6 to 3.4.8.

4.7.2 These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than given in Tables 3.4.6 to 3.4.8.

4.7.3 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on material from each cast. Where materials of more than one thickness are supplied from one cast, the thickest material is to be tested. The test specimens are to be prepared from material adjacent to that used for tests at ambient temperature. The axis of the test specimens, is to be between mid and quarter thickness of the material and the test specimens are to be machined to dimensions in accordance with the requirements of Chapter 2. The test procedure is also to be as detailed in Chapter 2, and the results are to comply with the requirements of the National or proprietary specifications.

4.7.4 As an alternative to 4.7.3, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes but, at the discretion of the Surveyors, occasional check tests of this type may be requested.

4.7.5 Values for the estimated average stress to rupture in 100 000 hours are given in Table 3.4.9 and may be used for design purposes.

Table 3.4.4 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – Normalised or normalised rolled

Grade of steel	Thickness mm (*see* Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360	>3 ≤16 >16 ≤40 >40 ≤63	205 195 185	360 – 480	26 26 25
410	>3 ≤16 >16 ≤40 >40 ≤63	235 225 215	410 – 530	24 24 23
460	>3 ≤16 >16 ≤40 >40 ≤63	285 255 245	460 – 580	22 22 21
490	>3 ≤16 >16 ≤40 >40 ≤63	305 275 265	490 – 610	21 21 20
360 FG	>3 ≤16 >16 ≤40 >40 ≤63	235 215 195	360 – 480	26 26 25
410 FG	>3 ≤16 >16 ≤40 >40 ≤63	265 245 235	410 – 530	24 24 23
460 FG	>3 ≤16 >16 ≤40 >40 ≤63	295 285 275	460 – 580	22 22 21
490 FG	>3 ≤16 >16 ≤40 >40 ≤63	315 315 305	490 – 610	21 21 21
510 FG	>3 ≤16 >16 ≤40 >40 ≤63	355 345 335	510 – 650	21

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.5 Mechanical properties for acceptance purposes: alloy steels – Normalised and tempered

Grade of steel	Thickness mm (see Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
13Cr Mo45	≤63	305	470–620	20
11Cr Mo910	≤16 >16 ≤63	275 265	480–630	18

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, e.g., for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.6 Mechanical properties for design purposes (*see* 4.7.1) **: carbon and carbon-manganese steels – As-rolled**

Grade of steel	Thickness mm	Design temperature °C (*see* Note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0,2% proof stress N/mm^2						
360 AR	≤ 40	154	153	152	145	128	108	102
410 AR	≤ 40	186	183	181	174	155	134	127
460 AR	≤ 40	218	213	210	203	182	161	153

NOTE
Maximum permissible design temperature is 350°C.

Table 3.4.7 Mechanical properties for design purposes (*see* 4.7.1)**: carbon and carbon-manganese steels – Normalised or controlled-rolled**

Grade of steel	Thickness mm (*see* Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0,2% proof stress N/mm^2								
360	>3 ≤16	183	175	172	168	150	124	117	115	113
	>16 ≤40	173	171	169	162	144	124	117	115	113
	>40 ≤63	166	162	158	152	141	124	117	115	113
410	>3 ≤16	220	211	208	201	180	150	142	138	136
	>16 ≤40	204	201	198	191	171	150	142	138	136
	>40 ≤63	196	192	188	181	168	150	142	138	136
460	>3 ≤16	260	248	243	235	210	176	168	162	158
	>16 ≤40	235	230	227	220	198	176	168	162	158
	>40 ≤63	227	222	218	210	194	176	168	162	158
490	>3 ≤16	280	270	264	255	228	192	183	177	172
	>16 ≤40	255	248	245	237	214	192	183	177	172
	>40 ≤63	245	240	236	227	210	192	183	177	172
360 FG	>3 ≤16	214	204	185	165	145	127	116	110	106
	>16 ≤40	200	196	183	164	145	127	116	110	106
	>40 ≤63	183	179	172	159	145	127	116	110	106
410 FG	>3 ≤16	248	235	216	194	171	152	141	134	130
	>16 ≤40	235	228	213	192	171	152	141	134	130
	>40 ≤63	222	215	204	188	171	152	141	134	130
460 FG	>3 ≤16	276	262	247	223	198	177	167	158	153
	>16 ≤40	271	260	242	220	198	177	167	158	153
	>40 ≤63	262	251	235	217	198	177	167	158	153
490 FG	>3 ≤16	297	284	265	240	213	192	182	173	168
	>16 ≤40	293	279	260	237	213	192	182	173	168
	>40 ≤63	286	272	256	234	213	192	182	173	168
510 FG	>3 ≤63	313	290	270	255	235	215	200	180	—

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.8 Mechanical properties for design purposes (*see* 4.7.1)**: alloy steels – Normalised and tempered**

Grade of steel	Thickness mm (see Note)	Design temperature °C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0,2% proof stress N/mm^2									
13CrMo 45	>3 ≤63	284	270	248	216	203	199	194	188	181	174
11CrMo 910	>3 ≤63	255	249	233	219	212	207	194	180	160	137

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.9 Mechanical properties for design purposes (*see* 4.7.5)**: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)**

Temperature °C	Grades of steel				
	Carbon and carbon-manganese			Low alloy	
	360FG 410FG 460FG	360 410 460	490 490FG 510FG	13CrMo 45	11CrMo 910
380	171	219	227	—	—
390	155	196	203	—	—
400	141	173	179	—	—
410	127	151	157	—	—
420	114	129	136	—	—
430	102	109	117	—	—
440	90	92	100	—	—
450	78	78	85	290	—
460	67	67	73	262	—
470	57	57	63	235	210
480	47	48	55	208	186
490	36	—	47	181	165
500	—	—	—	155	145
510	—	—	—	129	128
520	—	—	—	103	112
530	—	—	—	80	98
540	—	—	—	62	84
550	—	—	—	49	72
560	—	—	—	42	61
570	—	—	—	36	51
580	—	—	—	—	44

■ *Section 5*
Steels for machinery fabrications

5.1 General

5.1.1 Steel plates, sections or bars intended for use in the construction of major components of welded machinery structures, such as bedplates, crankcases, frames and entablatures, are to comply with one of the following alternatives:
(a) Any grade of normal strength structural steel as detailed in Section 2.
(b) Any grade of higher tensile structural steel as detailed in Section 3.
(c) Any grade of carbon-manganese boiler or pressure vessel steel as detailed in Section 4, except that for this application batch testing is acceptable. The size of a batch and the number of tensile tests are to be as detailed in Section 2.

5.1.2 The minus tolerances for products for machinery structures are to be in accordance with Table 3.5.1.

Table 3.5.1 Under thickness tolerances

Nominal thickness, *t* (mm)	Minus tolerance (mm)
5 ≤ *t* < 8	–0,4
8 ≤ *t* < 15	–0,5
15 ≤ *t* <25	–0,6
25 ≤ *t* < 40	–0,8
t ≥ 40	–1,0

5.2 Certification of materials

5.2.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements.

■ *Section 6*
Ferritic steels for low temperature service

6.1 Scope

6.1.1 This Section gives specific requirements for carbon-manganese and nickel alloy steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases.

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperatures is required.

6.1.3 Provision is made for plates and sections up to 40 mm thick.

6.1.4 Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.

6.2 Manufacture and chemical composition

6.2.1 All steels are to be in the killed and fine grain treated condition.

6.2.2 The chemical compositions of carbon-manganese steels are to comply with the appropriate requirements for Grades AH, DH, EH and FH strength levels 27S, 32, 36 and 40, *see* Table 3.3.2. For the uses defined in 6.1.1 and 6.1.2, however, these grades are to be designated LT–AH, LT–DH, LT–EH and LT–FH respectively.

6.2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 3.6.1.

Table 3.6.1 Chemical compositions of nickel alloy steels

<table>
<tr><th>Grade of steel</th><th>C</th><th>Si</th><th>Mn</th><th>Ni</th><th>P</th><th>S</th><th>Residual elements</th><th>Aluminium</th></tr>
<tr><td>1 1/2 Ni</td><td>0,18 max.</td><td rowspan="4">0,10 – 0,35</td><td>0,30 – 1,50</td><td>1,30 – 1,70</td><td rowspan="4">0,025 max.</td><td rowspan="4">0,020 max.</td><td rowspan="4">Cr 0,25 max.
Cu 0,35 max.
Mo 0,08 max.
Total 0,60 max.</td><td rowspan="4">Total 0,020% min.

Acid soluble 0,015% min.</td></tr>
<tr><td>3 1/2 Ni</td><td>0,15 max.</td><td rowspan="3">0,30 – 0,90</td><td>3,20 – 3,80</td></tr>
<tr><td>5Ni</td><td>0,12 max.</td><td>4,70 – 5,30</td></tr>
<tr><td>9Ni</td><td>0,10 max.</td><td>8,50 – 10,0</td></tr>
</table>

6.2.4 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

6.3 Heat treatment

6.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.6.2.

Table 3.6.2 Supply conditions

<table>
<tr><th>Grade</th><th>Plates</th><th>Sections and bars</th></tr>
<tr><td>LT – AH</td><td rowspan="2">N TM</td><td rowspan="3">Any</td></tr>
<tr><td>LT – DH</td></tr>
<tr><td>LT – EH</td><td rowspan="2">Normalised (see Note)
T.M.C.P.
Quenched and tempered</td></tr>
<tr><td>LT – FH</td><td>N TM</td></tr>
<tr><td>1 1/2 Ni
3 1/2 Ni
5Ni</td><td colspan="2">Normalised (see Note)
Normalised and tempered
Quenched and tempered</td></tr>
<tr><td>9Ni</td><td colspan="2">Double normalised and tempered
Quenched and tempered</td></tr>
<tr><td colspan="3">NOTE
Where the term ‘Normalised’ is used it does not include normalising rolling.</td></tr>
</table>

6.4 Mechanical tests

6.4.1 For plates, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

6.4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

6.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

6.4.4 One set of three Charpy V-notch impact test specimens is to be taken for each tensile test specimen required.

6.4.5 For plates, these impact test specimens are to be cut with the principal axis perpendicular to the final direction of rolling. For sections, the impact test specimens are to be taken longitudinally.

6.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Table 3.6.3. The ratio between the yield stress and the tensile strength is not to exceed 0,9 for normalised and TM steels and 0,94 for QT steels.

6.4.7 The average value for the three impact tests is to comply with the appropriate requirements given in Table 3.6.3. One individual value may be less than the required value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

6.4.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

6.4.9 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

6.5 Identification of materials

6.5.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

Table 3.6.3 **Mechanical properties for acceptance purposes** (*see* Note 1)

Grade of steel		Yield stress N/mm^2 min.	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min.	Charpy V-notch impact tests (*see* Note 3)	
					Test temp. °C	Impact energy
LT – AH	27S	265	400 – 530	22	0	
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – DH	27S	265	400 – 530	22	–20	Plates – transverse tests
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – EH	27S	265	400 – 530	22	–40	Average energy 27 J min
	32	315	440 – 590	22		
	36	355	490 – 620	21		
	40	390	510 – 650	20		
LT – FH	27S	265	400 – 530	22	–60	Sections and bars – longitudinal tests
	32	315	440 – 590	22		
	36	355	490 – 620	21		Average energy 41 J min
	40	390	510 – 650	20		
1$^1/_2$ Ni		275	490 – 640	22	–65	
3$^1/_2$ Ni		285	450 – 610	21	–95	
5Ni		390	540 – 740	21	–110	
9Ni		490	640 – 790	18	–196	

NOTES

1. These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.
2. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Fig. 3.6.1 and Fig. 3.6.2. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.
3. Impact tests are not required on thicknesses less than 6 mm.

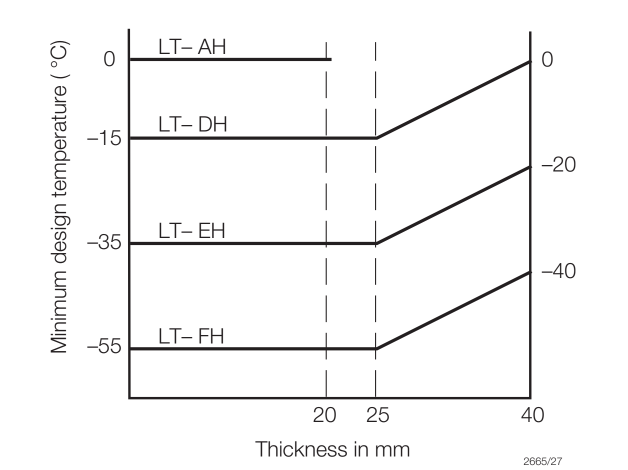


Fig. 3.6.1
Minimum design temperatures for carbon-manganese grades

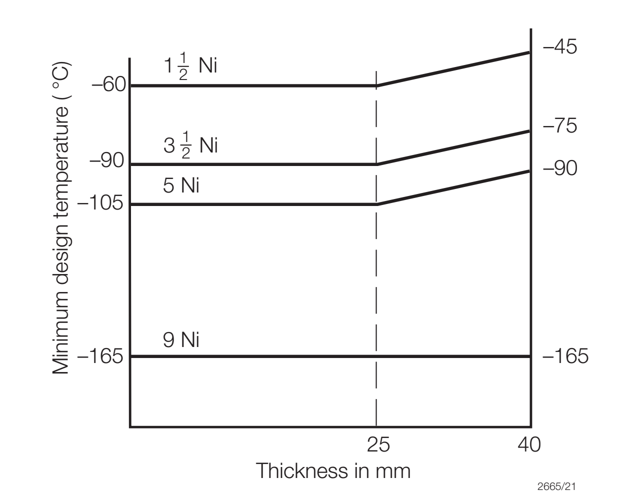


Fig. 3.6.2
Minimum design temperatures for nickel grades

6.6 Certification of materials

6.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 together with general details of the heat treatment. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Tables 3.3.2 or 3.6.1.

■ *Section 7* Austenitic and duplex stainless steels

7.1 Scope

7.1.1 Provision is made in this Section for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

7.1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

7.1.3 Austenitic stainless steels are also suitable for service at elevated temperatures, and for such applications the proposed specification should contain, in addition to the requirements of 7.1.6, minimum values for 0,2 and 1,0 per cent proof stresses at the design temperature.

7.1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

7.1.5 Duplex stainless steels are also suitable for service at temperatures up to 300°C, and for such applications the proposed specification should include, in addition to the requirements of 7.1.6, a minimum value for 0,2 per cent proof stress at the design temperature.

7.1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including, for the austenitic grades, both the 0,2 and 1,0 per cent proof stresses, is to be submitted for consideration and approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 3.7.1.

7.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 3.7.1.

7.3 Heat treatment

7.3.1 All materials are to be supplied in the solution treated condition.

Table 3.7.1 Chemical composition

Type and grade of steel	Chemical composition % (*see* Note)									
	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Austenitic										
304 L						17,0—20,0	8,0—13,0	—	0,10	—
304 LN						17,0—20,0	8,0—12,0	—	0,10—0,22	—
316 L	0,03					16,0—18,5	10,0—15,0	2,0—3,0	0,10	—
316 LN		1,0	2,0	0,045	0,03	16,0—18,5	10,0—14,5	2,0—3,0	0,10—0,22	—
317 L						18,0—20,0	11,0—15,0	3,0—4,0	0,10	—
317 LN						18,0—20,0	12,5—15,0	3,0—4,0	0,10—0,22	—
321	0,08					17,0—19,0	9,0—12,0	—	0,10	5 x C ≤ Ti ≤ 0,7
347	0,08					17,0—19,0	9,0—13,0	—	0,10	10 x C ≤ Nb ≤ 1,0
Duplex										
UNS S 31803	0,03	1,0	2,0	0,03	0,02	21,0—23,0	4,5—6,5	2,5—3,5	0,08—0,20	—
UNS S 32750	0,03	0,80	1,2	0,035	0,02	24,0—26,0	6,0—8,0	3,0—5,0	0,24—0,32	Cu 0,50 max.

NOTE
All figures are a maximum value except where a range is shown.

Table 3.7.2 Mechanical properties for acceptance purposes

Type and grade of steel	0,2% Proof stress (N/mm^2) minimum	1% Proof stress (N/mm^2) minimum	Tensile strength (N/mm^2) minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	—	620	25
UNS S 32750	550	—	795	15

7.4 Mechanical tests

7.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 4.4 and 6.4.1.

7.4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined from the longitudinal direction for each tensile test is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

7.4.3 Unless otherwise agreed, impact tests are not required from the austenitic grades of steel given in this Section.

7.4.4 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

7.4.5 The results of all tensile tests are to comply with the requirements of Table 3.7.2 or the approved specification.

7.5 Metallographic examination for sigma phase

7.5.1 The microstructure of all grades listed in Table 3.7.1 are to be examined metallographically at x400 magnification to demonstrate that sigma phase remains below 0,1 per cent of the observable area at a frequency of one per heat.

7.6 Intergranular corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

7.6.2 When required, one test of this type is to be carried out for each tensile test. The material for the test is to be taken adjacent to that for the tensile test.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be as given in 7.6.4, *see* Ch 2,9.

7.6.4 Wherever practical, exposed cut edges should be avoided. However, where any such edges are to remain after fabrication is completed, it is to be shown by an appropriate test, that the corrosion resistance is adequate for the cargoes expected to be encountered.

7.7 Clad plates

7.7.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

7.7.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 4, and the austenitic cladding material generally with the requirements of this Section.

7.7.3 The process of manufacture is to be specially approved and may be either by roll cladding, or by explosive bonding.

7.7.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent, and the acceptance standards for non-destructive examination.

7.8 Identification of materials

7.8.1 The particulars detailed in 1.11 are to be marked on all materials which have been accepted.

7.9 Certification of materials

7.9.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, where applicable, the results obtained from intercrystalline corrosion tests, and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements, as detailed in Table 3.7.1.

■ *Section 8*
Plates with specified through thickness properties

8.1 Scope

8.1.1 Provision is made in this Section for 'Z' grade plate and wide flat material with improved ductility in the through thickness or 'Z' direction, *see* Fig. 3.8.1. The use of this material is recommended for certain types of welded structures (*see* 1.2) in order to minimise the possibility of lamellar tearing either during fabrication or erection.

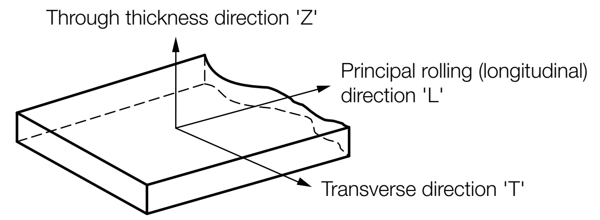


Fig. 3.8.1 Schematic of testing directions

8.1.2 Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

8.1.3 Provision is made for two grades Z25 and Z35. For normal ship applications the Z25 grade is applicable, whilst the Z35 grade is for more severe applications.

8.1.4 This 'Z' grade material is to comply with the requirements of Sections 2, 3, 4, 5 and 6 as appropriate, and the additional requirements of this Section.

8.1.5 The test procedure detailed in this Section may also be used to demonstrate that no unacceptable amount of banding of any detrimental phase, such as sigma is present, *see* 7.5.

8.2 Manufacture

8.2.1 All plates and wide flats are to be manufactured at works, which have been approved by LR for this quality of material.

8.2.2 It is recommended that the steel should be efficiently vacuum de-gassed. The sulphur content is not to exceed 0,008 per cent.

8.2.3 Consideration will be given to proposals for alternative methods of improving through thickness properties.

8.3 Test material

8.3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 mm for carbon and alloy steels, or 10 mm in the case of austenitic and duplex stainless steels.

8.3.2 For plates and wide flats, one test sample is to be taken close to the longitudinal centreline from one end of each rolled piece representing the batch, *see* Table 3.8.1 and Fig. 3.8.2. The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

Table 3.8.1 Batch size dependent on product and sulphur content

Product	$S > 0,005\%$	$S \leq 0,005\%$
Plates	Each piece (parent plate)	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment

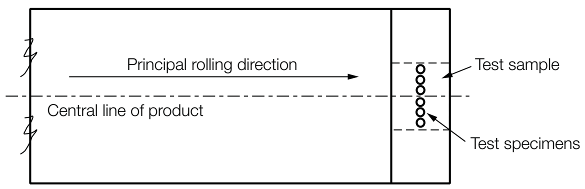


Fig. 3.8.2
Plate and wide flat sampling position

8.3.3 The dimensions of the test specimens are to be in accordance with Ch 2,2.1.12.

8.3.4 Alternatively, test sampling may be carried out in accordance with an accepted National or International Standard.

8.4 Mechanical tests

8.4.1 The three through thickness tensile test specimens are to be tested at ambient temperature, and for acceptance are to give a minimum average reduction of area value of not less than that shown in Table 3.8.2. Only one individual value may be below the minimum average, but should not be less than the minimum individual value shown for the appropriate grade.

Table 3.8.2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

8.4.2 If the average value fails to comply with 8.4.1, three additional tests may be made on specimens from the same test sample. The results of these tests are to be added to those previously obtained to form a new average, which for acceptance is to be not less than 25 per cent for grade Z25 or 35 per cent for grade Z35. No individual results in the re-test shall be below 25 per cent for grade Z25 or 35 per cent for grade Z35, *see* Fig. 3.8.3.

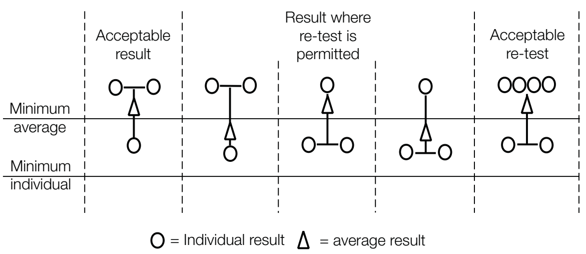


Fig. 3.8.3
Diagram showing acceptance/rejection and re-test criteria

8.4.3 Where batch testing is permitted, and failure after re-test occurs, the tested piece is to be rejected. Each remaining piece in the batch may be individually tested and accepted, based on satisfactory results.

8.4.4 If the fracture of a test specimen occurs in the weld or in the heat affected zone the test is to be regarded as invalid and is to be repeated on a new test specimen.

8.5 Non-destructive examination

8.5.1 All 'Z' grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with and in compliance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.6 Identification of materials

8.6.1 Products which comply with the requirements of this Section are to have the notation Z25 or Z35 added to the steel grade designation.

8.7 Certification of materials

8.7.1 The following information is required to be included on the certificate in addition to the appropriate steel grade requirements:
(a) Through thickness reduction in area (%), individual results and average.
(b) Steel grade with Z25 or Z35 notation.

8.7.2 Steel grade requirements are to comply with Sections 1 to 7.

■ *Section 9*
Bars for welded chain cables

9.1 Scope

9.1.1 Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) of stud link chain cable for the anchoring and mooring of ships and five Grades (R3, R3S, R4, R4S and R5) of offshore mooring cable.

9.1.2 For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

9.1.3 For the offshore grades, R3, R3S, R4, R4S and R5, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer. Approval of a higher grade does not cover approval of a lower grade, as all grades must be individually approved.

9.1.4 For all grades, approval is normally given for diameters of bars no greater than those of the bars used in procedure tests.

9.2 Manufacture

9.2.1 All grades of bar material are to be made from killed steel, and all grades of bar material except for Grade U1 chain cables are to be fine grained. For Grades R4S and R5 the austenite grain size is to be 6 or finer, in accordance with ASTM E112.

9.2.2 The bars are to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

9.2.3 The rolling reduction ratio of bars for Grades R3, R3S, R4, R4S and R5 must be at least 5:1.

9.3 Chemical composition

9.3.1 For Grades U1, U2 and U3 the chemical composition should be generally within the limits given in Table 3.9.1.

9.3.2 For Grades R3, R3S, R4, R4S and R5 the chemical composition is to comply with an approved specification, *see* 9.2.2.

9.3.3 For Grades R4, R4S and R5 chain cable the steel should contain a minimum of 0,2 per cent molybdenum. The reported composition is to include the contents of antimony, arsenic, tin, copper, nitrogen, aluminium and titanium.

9.3.4 For Grades R4S and R5 the steel used must be vacuum degassed.

9.4 Heat treatment

9.4.1 Unless stipulated otherwise, the bars are to be supplied in the as-rolled condition, but the supplier is to be advised by the chain manufacturer of the heat treatment to be used for the completed chain in order that the mechanical test specimens may be tested in the condition of heat treatment used for the chain.

9.4.2 For Grades U1 and U2, the samples selected from each batch may be tested either in the as-rolled condition, or after heat treatment where the chain is to be used in the heat treated condition, in full cross-section and in a manner simulating the heat treatment applied to the finished cable.

9.4.3 For Grades U3, R3, R3S, R4, R4S and R5 the sample is to be tested after heat treatment as detailed in 9.4.2.

9.5 Embrittlement tests

9.5.1 For Grades R3, R3S, R4, R4S and R5 the bar manufacturer is to provide evidence that the material is not susceptible to strain ageing, or to temper brittleness under the conditions of manufacture of the chain. The results of the relevant tests are to be reported to LR at the approval stage. Approval will be restricted to the specified steel composition and if later this is altered then re-approval will be required. Temper brittleness testing may be waived, if the chain is to be quenched after tempering.

9.5.2 Each heat of steel bars of grades R3S, R4, R4S and R5 is to be tested for hydrogen embrittlement (*see* Ch 2,5.3). In the case of continuous casting, test samples representing both the beginning and the end of the heat are to be taken. In the case of ingot casting, test samples representing two different ingots are to be taken.

9.5.3 Each sample is to be heat treated in a manner simulating the heat treatment of the finished chain. From each sample, two specimens are to be prepared from the mid-diameter of the bar and tested in accordance with Ch 2,5.3.

9.5.4 The ratio Z_1/Z_2 is to be greater than or equal to 0,85, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

9.5.5 If the requirement is not met, the material is to be subjected to a hydrogen degassing treatment which is subject to approval by LR. Further tests are to be performed after degassing.

9.6 Mechanical tests

9.6.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same cast. A suitable length from one bar in each batch is to be selected for test purposes. Test pieces are to be taken from the positions as shown in Fig. 3.9.1.

9.6.2 For all grades, one tensile test is to be taken from each sample length selected. Additionally, for Grades U3, R3, R3S, R4, R4S and R5 material, one set of three Charpy V-notch impact test specimens is to be prepared. Impact tests are also required for Grade U2 when the chain is to be supplied in as-welded condition.

Table 3.9.1 Chemical composition of killed steel bars

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	Nb max.	V max.	N max.	Cr max.	Cu max.	Ni max.	Mo max.
U1	0,20	0,15–0,35	0,40 min.	0,04	0,04	–	–	–	–	–	–	–	–
U2	0,24	0,15–0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	–	–	–	–	–	–	–
U3	0,33	0,15–0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,05 *see* Note 2	0,10 *see* Note 2	0,015	0,25	0,35	0,40	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

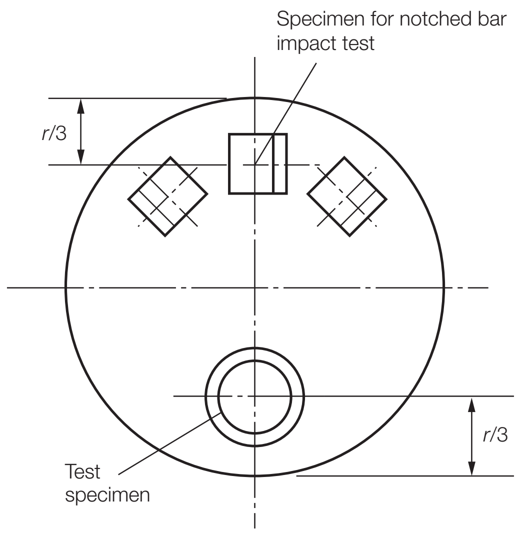


Fig. 3.9.1 Sampling of steel bars

9.6.3 The results of all tensile and, where applicable, impact tests are to be in accordance with the appropriate requirements of Table 3.9.2.

9.6.4 Failure to meet the requirements will result in the rejection of a batch of material, unless it is clearly attributed to improper simulated heat treatment. This is to be confirmed to be to the satisfaction of LR, and further heat treatment and testing will be required prior to acceptance.

9.7 Structure and hardenability tests

9.7.1 For Grades R4S and R5, the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusion. These must be acceptable for the final product.
(b) Macro etching on a representative sample, in accordance with ASTM E381 or equivalent. This must be free from any injurious segregation or porosity.
(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

9.8 Dimensional tolerances

9.8.1 The tolerances on diameter and ovality of the bar are to be in accordance with Table 3.9.3.

Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_0}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
U1	–	370–490	25	—	—	—	—
U2	295	490–690	22	—	0 (*see* Note 1)	27	—
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35	— —
R3	410 (*see* Note 3)	690 minimum (*see* Note 3)	17	50	0 –20 (*see* Note 2)	60 40	50 30
R3S	490 (*see* Note 3)	770 minimum (*see* Note 3)	15	50	0 –20 (*see* Note 2)	65 45	53 33
R4	580 (*see* Note 3)	860 minimum (*see* Note 3)	12	50	–20	50	36
Grade R4S (*see* Note 4)	700 (*see* Note 3)	960 minimum (*see* Note 3)	12	50	–20	56	40
Grade R5 (*see* Note 4)	760 (*see* Note 3)	1000 minimum (*see* Note 3)	12	50	–20	58	42

NOTES
1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C, at the option of LR.
3. The ratio of yield strength to tensile strength should not exceed 0,92.
4. The maximum hardness for R4S is to be HB330, and for R5 is to be HB340.

Table 3.9.3 Dimensional tolerance of bar stock

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness ($d_{max} - d_{min}$) mm
≤20	–0/+1,0	0,60
>20 ≤25	–0/+1,0	0,60
>26 ≤35	–0/+1,2	0,80
>36 ≤50	–0/+1,6	1,10
>51 ≤80	–0/+2,0	1,50
>81 ≤100	–0/+2,6	1,95
>101 ≤120	–0/+3,0	2,25
>121 ≤160	–0/+4,0	3,00
>161 ≤210	–0/+5,0	4,00

9.9 Non-destructive examination

9.9.1 For the grades U1, U2 and U3 all bars are to be free from internal and surface defects that might impair proper workability, use and strength. Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the acceptable tolerances are not exceeded.

9.9.2 For the R3, R3S, R4, R4S and R5 grades all bars are to be inspected by a magnetic particle or eddy current method, and are also to be subjected to ultrasonic examination.

9.9.3 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

9.9.4 All non-destructive examination operators are to be qualified in the method of non-destructive examination, to a minimum of Level II in accordance with a recognised standard.

9.9.5 The bars are to be free from pipes, cracks, flakes, and injurious surface defects such as seams, laps, and rolled-in mill scale. Longitudinal discontinuities may be removed by blending to a smooth contour provided that their depth is not greater than 1 per cent of the bar diameter, and that the required diameter tolerances are not compromised. The contour radiuses are to be a minimum of four times the excavation depth.

9.9.6 The frequency of non-destructive testing may be reduced at the discretion of LR, provided statistical evidence is available that the required quality is achieved consistently.

9.10 Identification

9.10.1 Each bar is to be identified in accordance with 1.10 and, in addition, is to be marked with the appropriate grade of chain cable.

9.11 Certification of materials

9.11.1 Each consignment of bars is to be accompanied by a certificate of a type and in accordance with 1.12, but with the addition of the grade of chain cable, the rolling reduction ratio, the results of the hydrogen embrittlement,micro inclusion, macro etch and hardenability tests, where required by each grade.

■ *Section 10* High strength quenched and tempered steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for weldable high strength quenched and tempered steel plates and wide flats up to 70 mm thick. However, special consideration will be given to thicknesses up to 50 mm supplied in the TM rolled condition.

10.1.2 Plates and wide flats exceeding 70 mm in thickness as well as other product forms may also be supplied in accordance with the requirements of this Section, provided that the prior agreement of LR is obtained.

10.1.3 The steels may be supplied in six strength levels with minimum yield stresses of 420, 460, 500, 550, 620 and 690 N/mm^2 respectively.

10.1.4 Each strength level is sub-divided into four grades AH, DH, EH and FH, differing essentially in the required levels of notch toughness.

10.1.5 For the designation to fully identify a steel and its properties, the appropriate grade letter should precede the strength level number, e.g., EH 42.

10.1.6 Steels differing in strength level, mechanical properties and chemical composition from those detailed in this Section may be supplied, subject to special approval from LR. Such steels are to have the letter 'S' after the agreed identification mark.

10.2 Manufacture and chemical composition

10.2.1 The steels are to be fully killed and fine grain treated.

10.2.2 The chemical composition is to comply with the requirements of the approved manufacturing specification and the limits set in Table 3.10.1.

Table 3.10.1 Chemical composition

Grade	AH	DH	EH	FH
Carbon % max	0,21	0,20		0,18
Manganese % max	1,70	1,70		1,60
Silicon % max	0,55	0,55		0,55
Phosphorus % max	0,035	0,030		0,025
Sulphur % max	0,035	0,030		0,025
Nitrogen % max	0,020	0,020		0,020
Grain refining elements (*see* Note 1)				
Aluminium (acid soluble) % min (*see* Note 2)	0,015			
Niobium %	0,02—0,05			
Vanadium %	0,03—0,10			
Titanium % max	0,02			
Total (Nb + V + Ti) % max	0,12			

NOTES
1. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the content is to be within the limits given in the Table. When used in combination, these limits are not applicable but the proportions of the grain refining elements are to be in accordance with the approved manufacturing specification.
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is not to be less than 0,020%.
3. Alloying elements and residual elements other than those listed in the Table (e.g., Ni, Cr, Cu, Mo and B) are to be included in the approved manufacturing specification.

10.2.3 The cold cracking susceptibility, P_{cm}, may be used as an alternative to the carbon equivalent for evaluating weldability. It is to be calculated from the ladle analysis using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the approved manufacturing specification.

10.3 Mechanical properties

10.3.1 At least one tensile test piece and one set of three Charpy V-notch impact tests specimens are to be taken from each piece as heat treated.

10.3.2 For continuously heat treated products, one tensile test piece and a set of three impact test specimens are to be taken from each plate as heat treated.

10.3.3 For plates and wide flats with widths exceeding 600 mm, the tensile and impact test specimens are to be taken with their axes transverse to the final direction of rolling. For other products, the impact test specimens are to be taken in the longitudinal direction but the tensile test specimens may be taken in either the longitudinal or transverse direction as agreed with LR.

10.3.4 The results of all tests are to comply with the appropriate requirements of Table 3.10.2.

10.3.5 Where standard subsidiary impact test specimens are necessary, *see* Ch 2,3.2.4.

10.4 Identification of materials

10.4.1 The particulars detailed in 1.11 are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

10.5 Certification of materials

10.5.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.12 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Table 3.10.1.

Table 3.10.2 **Mechanical properties for acceptance purposes**

Grade	Yield stress N/mm^2 min. (*see* Note 1)	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum (*see* Note 2)		Charpy V-notch impact tests (*see* Note 4)		
					Test temperature	Average energy J minimum	
			Transverse	Longitudinal	°C	Transverse	Longitudinal
AH 42 DH 42 EH 42 FH 42	420	530 – 680	18	20	0 –20 –40 –60	28	42
AH 46 DH 46 EH 46 FH 46	460	570 – 720	17	19	0 –20 –40 –60	31	46
AH 50 DH 50 EH 50 FH 50	500	610 – 770	16	18	0 –20 –40 –60	33	50
AH 55 DH 55 EH 55 FH 55	550	670 – 830	16	18	0 –20 –40 –60	37	55
AH 62 DH 62 EH 62 FH 62	620	720 – 890	15	17	0 –20 –40 –60	41	62
AH 69 DH 69 EH 69 FH 69	690	770 – 940	14	16	0 –20 –40 –60	46	69

NOTES

1. Where a distinct yield stress indication is not obtainable during tensile testing the 0,2% proof stress is applicable.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2) the minimum elongation is to be:

Thickness mm		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Strength levels								
Elongation %	42	11	13	14	15	16	17	18
	46	11	12	13	14	15	16	17
	50 and 55	10	11	12	13	14	16	16
	62	9	11	12	12	13	14	15
	69	9	10	11	11	12	13	14

These values apply to transverse specimens. Where the use of longitudinal specimens has been agreed, the values are to be increased by 2%.

3. The ratio of yield strength to tensile strength should not exceed 0,94.
4. Impact tests are not required on thicknesses less than 6 mm.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Castings are to be made at foundries approved by LR. The steel used is to be manufactured by a process approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognised good practice and is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the chemical composition and/or thickness of the casting. The affected areas are to be either machined or ground smooth for a depth of about 2 mm unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required to find any cracking in way of the cut surfaces.

1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests will be required*, see also* the requirements of 1.9.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved specification.

1.3.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.3.3 The locations of all chaplets are to be noted and to be subject to close visual inspection (and when necessary ultrasonic examination) to ensure complete fusion.

1.4 Chemical composition

1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Section of this Chapter. Where general overall limits are specified, the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the castings.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.5 Heat treatment

1.5.1 All castings are to be heat treated in accordance with the requirements given in the relevant Section of this Chapter.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control. The furnace dimensions are to be such as to allow the steel castings to be uniformly heated to the necessary temperature. Sufficient thermocouples are to be connected to the steel castings to show that their temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Alternative procedures are to be approved by LR, Materials and NDE department. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the individual steel castings, the heat treatment temperature and time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. In the case of very large components which require heat treatment, alternative methods will be specially considered.

1.5.3 If a casting is locally reheated, or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

1.6 Test material and test specimens

1.6.1 Test material sufficient for the tests specified in Sections 2 to 9 and for possible re-test purposes is to be provided for each casting. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm.

1.6.2 The test samples are not to be detached from the casting until the heat treatment specified in 1.5.1 has been completed and they have been properly identified.

1.6.3 As an alternative to 1.6.1 and 1.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted, using separately cast test samples of suitable dimensions. The test samples are to be properly identified and heat treated together with the castings which they represent. At least one test sample is to be provided for each batch of castings.

1.6.4 The test specimens are to be prepared in accordance with the requirements of Chapter 2. Tensile test specimens are to have a cross-sectional area of not less than 150 mm^2.

1.6.5 Re-test procedures are to be in accordance with Ch 2,1.4.

1.7 Visual and non-destructive examination

1.7.1 This Section gives the general requirements for non-destructive examination of steel castings. As an alternative, castings may be examined in accordance with a National Specification, provided it gives reasonable equivalence to these Rules.

1.7.2 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting.

1.7.3 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.7.4 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.7.5 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or dye penetrant inspection (for austenitic stainless steel castings, *see* Section 8) in accordance with 1.7.9, unless more specific requirements for non-destructive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

1.7.6 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be in accordance with the requirements of Ch 1,5.

1.7.7 The manufacturer is to provide the Surveyor with a signed report confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects.

1.7.8 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable for the final inspection. Prods are not permitted on finished machined surfaces.

1.7.9 Where required, magnetic particle or dye penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:

(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(d) In way of welds.
(e) In way of chaplets.
(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

1.7.10 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.

(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g., bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
(f) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.

1.7.11 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in 1.7.10. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

1.7.12 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7.13 The general acceptance criteria given in 2.5.2 are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.8 Pressure testing

1.8.1 Where required by the relevant Rules, castings are to be pressure tested in the final machined condition before final acceptance. These tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

1.9 Rectification and dressing of castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or dye penetrant testing.

1.9.2 Where flame scarfing or arc-air gouging is used, the requirements detailed in 1.2.2 are to apply.

1.9.3 Grinding wheels for use on austenitic stainless steels are to be of an iron-free type and shall have been used only on stainless steels.

1.9.4 All proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to satisfy himself that the number, position and size of the defects are such that the casting can be effectively repaired.

1.9.5 A statement and/or sketch detailing the extent and position of all welds is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where welding is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out welding unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.8 Any excavations are to be of suitable shape to allow good access for welding and, after final preparation for welding, are to be re-examined by suitable non-destructive testing methods to ensure that all defective material has been eliminated.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the welds.

1.9.10 Welding is to be carried out under cover, in positions free from draughts and adverse weather conditions. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 1.9.12, and the results of these tests are to be presented to the Surveyor.

1.9.12 After welding is completed, the castings are to be given the heat treatment specified in Sections 2 to 9, or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment required will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

1.9.13 Special consideration may be given to a local stress relieving heat treatment. where both the welded area is small and machining of the casting has reached an advanced stage, prior agreement is to be obtained from LR in writing. The welding procedure is to be such that residual stresses are minimised.

1.9.14 On completion of heat treatment, all welds and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive examination used.The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, Tables 13.2.4 to 13.2.6 in Chapter 13, as appropriate.

1.9.15 Where no welding has been made on a casting, the manufacturer is to provide the Surveyor with a written statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of all welds made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.9.17 For rectification of defective steel castings for crankshafts, *see* 4.7.

1.10 Identification of castings

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities to trace the castings when required.

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:
(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) Manufacturer's name or trade mark.
(c) LR or Lloyd's Register and the abbreviated name of LR's local office.
(d) Personal stamp of Surveyor responsible for inspection.
(e) Test pressure, where applicable.
(f) Date of final inspection.

1.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and steel grade.
(c) Identification number.
(d) Steel-making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 Where applicable, the manufacturer is to provide a signed report regarding non-destructive examination as required by 1.7.7 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

■ *Section 2* Castings for ship and other structural applications

2.1 Scope

2.1.1 The requirements for carbon-manganese steel castings, intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature, are given in this Section.

2.1.2 Provision is made for two quality grades, Normal and Special.

2.1.3 Where it is proposed to use carbon-manganese steels of higher specified minimum tensile strength than required by 2.4.3, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2.2 Chemical composition

2.2.1 The chemical composition of ladle samples is to comply with Table 4.2.1.

2.2.2 For the Special grade, the product of the aluminium and nitrogen contents is to comply with the following formula:

$$(\%\ Al_{acid\ sol}\ x\ \%\ N)\ 10^5 \leq 60$$

2.2.3 For the Special grade, a check chemical analysis on the product or a test bar is mandatory. The check analysis on the product or test bar is to comply with the requirements of Table 4.2.1.

Table 4.2.1 Chemical composition

Quality grade	Normal	Special (*see* Note 3)
Carbon	0,23% max.	0,23% max.
Silicon	0,60% max.	0,60% max.
Manganese	0,70–1,60%	0,70–1,60%
Sulphur	0,040% max.	0,035% max.
Phosphorus	0,040% max.	0,035% max.
Aluminium – (acid soluble)	—	0,015–0,080% (*see* Notes 1 and 2)
Residual elements:		
Copper	0,30% max.	0,30% max.
Chromium	0,30% max.	0,30% max.
Nickel	0,40% max.	0,40% max.
Molybdenum	0,15% max.	0,15% max.
Total	0,80% max.	0,80% max.

NOTES
1. The total aluminium content may be determined instead of the acid soluble content, in which case the total aluminium content is to be 0,020–0,10%.
2. Grain refining elements other than aluminium may be used subject to special agreement with LR.
3. For the Special grade, the nitrogen content is to be determined.

2.3 Heat treatment

2.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

2.3.2 For larger castings where a coarse of microstructure may be present in heavier thickness, a double austenising heat treatment may be required to ensure adequate grain refinement. A coarse microstructure will be indicated by an increased attenuation of approxiamtely 30 dB/m at 2 MHz during ultrasonic examination.

2.3.3 Following weld repair and or the attachment of handling brackets, all castings are to be subject to post weld heat treatment at a temperature of not less than 550°C before delivery.

2.4 Mechanical tests

2.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

2.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

2.4.3 The results of these tests are to comply with the following requirements:

Yield stress	200 N/mm^2 min.
Tensile strength	400 N/mm^2 min.
Elongation on $5{,}65\sqrt{S_o}$	25% min.
Reduction of area	40% min.

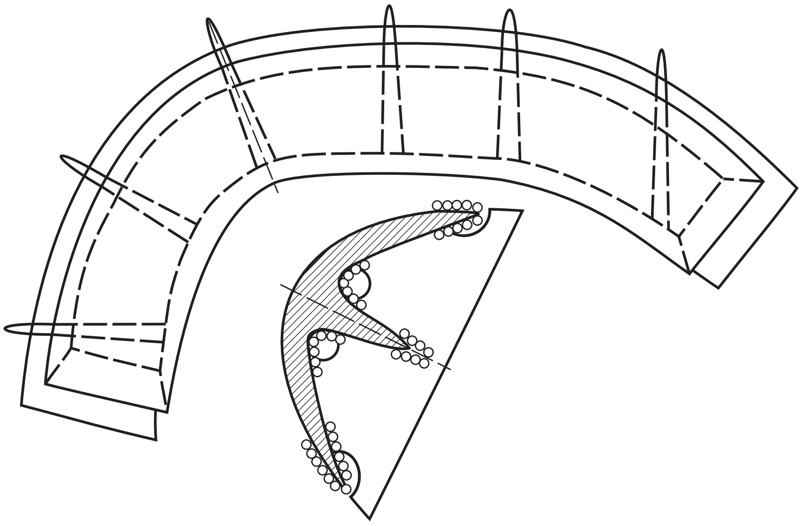
2.4.4 A set of three Charpy V-notch impact test specimens is to be provided with each casting in the Special grade. These may be taken from a small extension of the thickest part of the casting or from a block cast integrally with the casting and having dimensions representative of the largest section thickness of the casting. These are to be tested in accordance with Chapter 2 and are to have an average energy of not less than 27J at 0°C.

2.5 Non-destructive examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with 1.7. The type and extent of non-destructive examination of castings for other structural applications are to be specially agreed by the Surveyor.

2.5.2 The extent and methods of non-destructive examination to be applied to typical hull steel castings are shown in Figs. 4.2.1 to 4.2.6 in addition to the areas specified in 1.7.9 and 1.7.10.

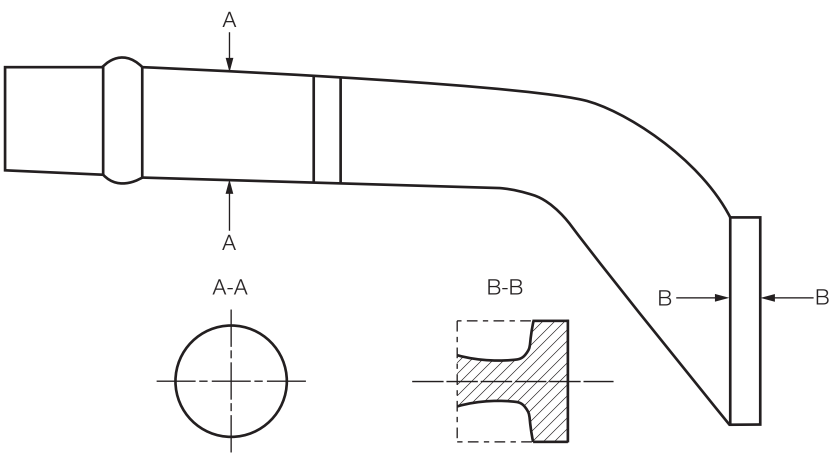
2.5.3 Acceptance levels for Visual Inspection are to be taken as follows:
(a) No cracks or hot tears are permitted.
(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.
(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by 2.6.



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing

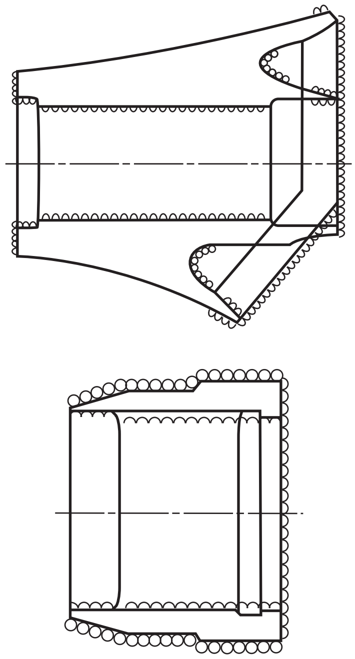
Fig. 4.2.1 Extent of non-destructive evaluation for stern frame castings



Location of non-destructive examination

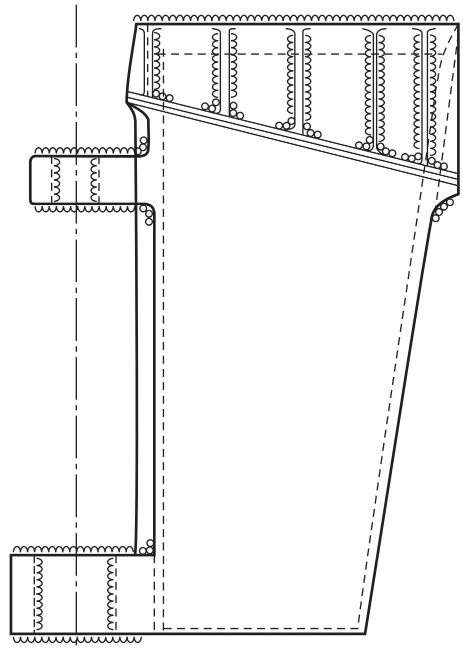
All surfaces: Visual examination
Magnetic particle and ultrasonic testing

Fig. 4.2.2 Extent of non-destructive evaluation for rudder stock castings



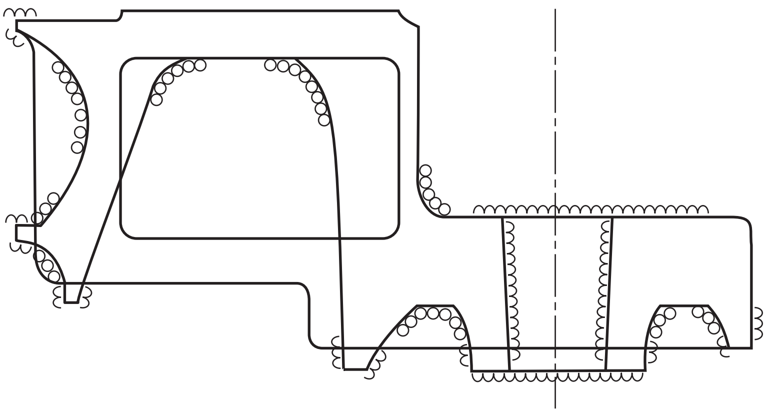
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and ultrasonic testing
3. Location indicated with (⌢⌢⌢): Ultrasonic testing

Fig. 4.2.3
Extent of non-destructive evaluation for stern boss castings



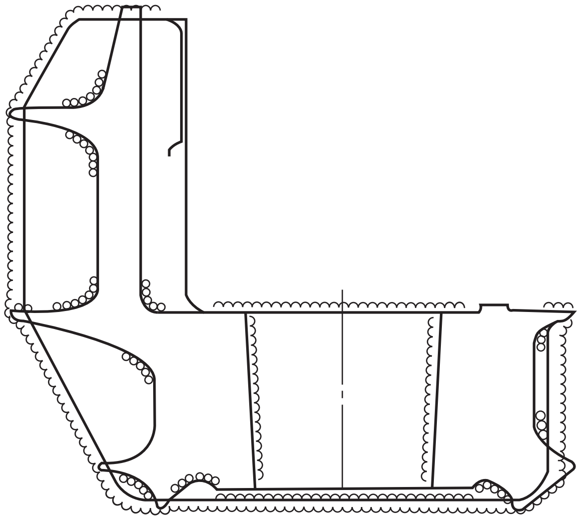
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌢⌢⌢): Ultrasonic testing

Fig. 4.2.4
Extent of non-destructive evaluation for rudder hanging castings



Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌢⌢⌢): Ultrasonic testing

Fig. 4.2.5 Extent of non-destructive evaluation for rudder (upper part) castings



Location of non-destructive examination

1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with (⌣⌣⌣): Ultrasonic testing

Fig. 4.2.6
Extent of non-destructive evaluation for rudder (lower part) castings

2.6 Acceptance levels for surface crack detection

2.6.1 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.

(b) **Non-linear indication**. An indication of circular or elliptical shape with a length less than three times the width.

(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less, edge-to-edge.

(d) **Open indication**. An indication visible after removal of the magnetic particles, or that can be detected by the use of contrast dye penetrant.

(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles, or that cannot be detected by the use of contrast dye penetrant.

(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location, relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or dye penetrant testing (PT) are;

(a) Level MT1/PT1 – fabrication weld preparation areas.

(b) Level MT2/PT2 – other locations indicated on Figs. 4.2.1 to 4.2.6.

The acceptance criteria are shown in Table 4.2.2. Cracks and hot tears are not acceptable.

2.6.4 Acceptance criteria for ultrasonic testing are shown in Table 4.2.3 as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks or hot tears, are not acceptable.

2.6.5 Level UT1 is applicable to the following:

(a) Fabrication weld preparations for a distance of 50 mm.

(b) 50 mm depth from the final machined surface including boltholes.

(c) Fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end.

(d) Castings subject to cyclic bending stresses, e.g., rudder horn, rudder castings and rudder stocks, the outer one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

2.6.6 Level UT2 is applicable to the following:

(a) For locations which are not specified in 2.6.5, nominated for ultrasonic testing in Figs. 4.2.1 to 4.2.6 or on the inspection plan.

(b) Positions outside locations nominated for level UT1 examination where feeders and gates have been removed.

(c) Castings subject to cyclic bending stresses, at the central one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm (*see* Note 2)
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4, *see* Note 1 4, *see* Note 1 4, *see* Note 1	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-Linear Linear Aligned	10 6 6	7 5 5

NOTES
1. Minimum of 30 mm between relevant indications.
2. In weld repairs, the maximum dimension is 2 mm.

Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings

Quality level	Allowable disc shape according to the Distance-Gain Size (DGS), mm	Maximum number of indications to be registered, *see* Note 1	Allowable length of linear indications, mm, *see* Note 2
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0

NOTES
1. Grouped in an area measuring 300 x 300 mm.
2. Measured on the scanning surface.

2.6.7 Ultrasonic acceptance criteria for casting areas not nominated in Figs. 4.2.1 to 4.2.6 will be subject to special consideration, based on the anticipated stress levels and the type, size and position of the discontinuity.

2.6.8 Parts which are welded are to be examined by the same method as at the initial inspection as well as by additional methods as required by the Surveyor.

■ *Section 3* Castings for machinery construction

3.1 Scope

3.1.1 This Section gives the material requirements for carbon-manganese steel castings intended for use in machinery construction and which are not within the scope of Sections 4 to 7.

3.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 3.2.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.3 The manufacture or repair of cast steel connecting rods is not permitted, except where the manufacturing and quality control procedures have been approved by LR. For approval purposes, tests are to be carried out at the place of manufacture using the proposed process to demonstrate that the castings are sound. Tests are to be carried out to confirm that the appropriate mechanical properties are attained within the casting, including areas where weld repairs have been performed. Any changes to manufacturing, repair and quality control procedures are to be submitted to LR for approval, *see also* Ch 1,2.2.

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples is to comply with the following limits, except as specified in 3.2.2:

Carbon	0,40% max.
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

3.2.2 Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent.

3.2.3 Proposals to use steels with higher carbon content, or alloy steels, for welded construction will be subject to special consideration.

3.3 Heat treatment

3.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

3.4.3 Table 4.3.1 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate levels of minimum tensile strength may be specified, in which case minimum values for yield stress, elongation and reduction of area may be obtained by interpolation.

Table 4.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel castings for machinery construction

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
400–550	200	25	40
440–590	220	22	30
480–630	240	20	27
520–670	260	18	25
560–710	300	15	20
600–750	320	13	20

3.4.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.3.1.

3.4.5 The results of all tensile tests are to comply with the requirements of Table 4.3.1 appropriate to the specified minimum tensile strength.

3.4.6 For alloy steel castings and carbon-manganese steel castings containing more than 0,40 per cent carbon, the results of all mechanical tests are to comply with an approved specification.

3.4.7 When a casting, or a batch of castings, has failed to meet the mechanical test requirements, it may be re-heat treated and re-submitted for acceptance tests but this may not be carried out more than twice, *see* Ch 1,4.6.

3.5 Non-destructive examination

3.5.1 All piston crowns and cylinder covers are to be examined by ultrasonic testing. In addition, where these castings are intended for engines having a bore size larger than 400 mm, they are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.2 Engine bedplate castings are to be examined by ultrasonic and magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.3 Turbine castings are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

3.5.4 Other castings are to be examined by non-destructive methods where specified.

■ *Section 4* Castings for crankshafts

4.1 Scope

4.1.1 This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built crankshafts.

4.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 4.3.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For alloy steels, the specified minimum tensile strength is not to exceed 700 N/mm^2.

4.2 Manufacture

4.2.1 The method of producing combined web and pin castings is to be approved. For this purpose, tests to demonstrate the soundness of the casting and the properties at important locations may be required.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with the following limits:

Carbon	0,40% max. (*but see* 4.7.4(c))
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

4.4 Heat treatment

4.4.1 Castings are to be supplied either:

(a) fully annealed and cooled in the furnace to a temperature of 300°C or lower; or

(b) normalised and tempered at a temperature of not less than 550°C, and cooled in the furnace to a temperature of 300°C or lower.

4.5 Mechanical tests

4.5.1 Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer.

4.5.2 Not less than one tensile test and three impact tests are to be made on material representing each casting. The impact tests are to be carried out at ambient temperature.

4.5.3 Table 4.4.1 gives the minimum requirements for yield stress and elongation corresponding to different strength levels, and it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2 to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 4.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel castings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests average energy J minimum (*see* Note)
400–550	200	28	45	32
440–590	220	26	45	28
480–630	240	24	40	25
520–670	260	22	40	20
550–700	275	20	35	18

NOTE
Impact tests are to be made at ambient temperature.

4.5.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.4.1.

4.5.5 The results of all tests are to comply with the requirements of Table 4.4.1 appropriate to the specified minimum tensile strength. For the impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

4.6 Non-destructive examination

4.6.1 Magnetic particle examination is to be carried out over all surfaces in accordance with Fig. 4.4.1.

4.6.2 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in Fig. 4.4.2. Alternative ultrasonic procedures may be submitted for approval.

4.7 Rectification of defective castings

4.7.1 The requirements of 1.9 apply, except where amended by this Section.

4.7.2 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining the surface where there is excess metal on the Rule dimension.

4.7.3 Subject to prior agreement and submission of the detailed welding procedure for approval by LR, welding may be carried out prior to the final austenitising heat treatment.

4.7.4 Approval for welding will not be given in the following circumstances:

(a) For the rectification of repetitive defects caused by improper foundry technique or practice.
(b) For the building up by welding of surfaces or large shallow depressions.
(c) Where the carbon content of the steel exceeds 0,30 per cent.
(d) Where the carbon equivalent of the steel, given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ exceeds 0,65 per cent.

4.7.5 Provided that the Surveyors are satisfied that welding is justified, they may also authorise welding to the surfaces of crankwebs, following the final austenitising heat treatment, within the following limits:

(a) In general, the volume of the largest groove which is to be welded is not to exceed 3,2t cm^3, where t is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed 9,6t cm^3 per crankweb.
(b) The welds do not extend within the cross-hatched zones marked on Fig. 4.4.3 for semi-built crank throws.
(c) Larger welds on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

4.7.6 Subsequent to the final austenitising heat treatment, welding may be authorised in the surface of the bore for the journal (or pin) within the following limits:

(a) In general, the welds are to be not less than 125 mm apart.
(b) The welds are not to be located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Fig. 4.4.3.
(c) The volume of the largest weld is to be not more than 1,1t cm^3, where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

4.7.7 After all defective material has been removed from a region, and this has been proven in the presence of the Surveyor by magnetic particle inspection or other suitable method, the excavation is to be suitably shaped to allow good access for welding.

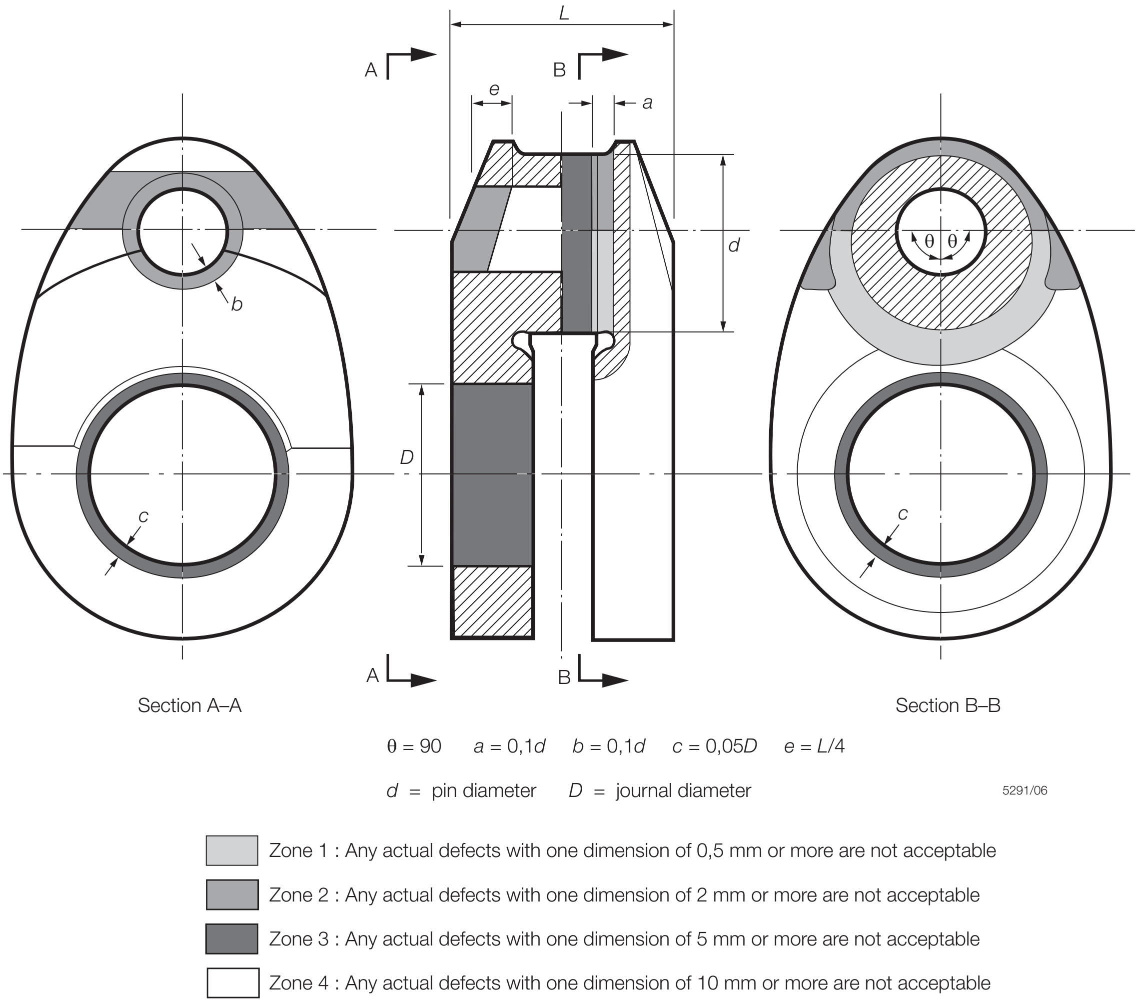


Fig. 4.4.1 Magnetic particle inspection acceptance levels

4.7.8 At the discretion of the Surveyor, the size of a groove may be increased beyond the limiting sizes given in 4.7.5 or 4.7.6, if the removal of further metal will facilitate welding.

4.7.9 Welding is to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

4.7.10 All castings are to be given a preliminary refining heat treatment prior to the commencement of welding. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is placed in the furnace for post-weld heat treatment.

4.7.11 Where welding is carried out after the final austenitising heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600ºC, *see also* 1.5.2.

4.7.12 Welds are to be dressed smooth by grinding. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see* 1.9.15 and 1.9.14.

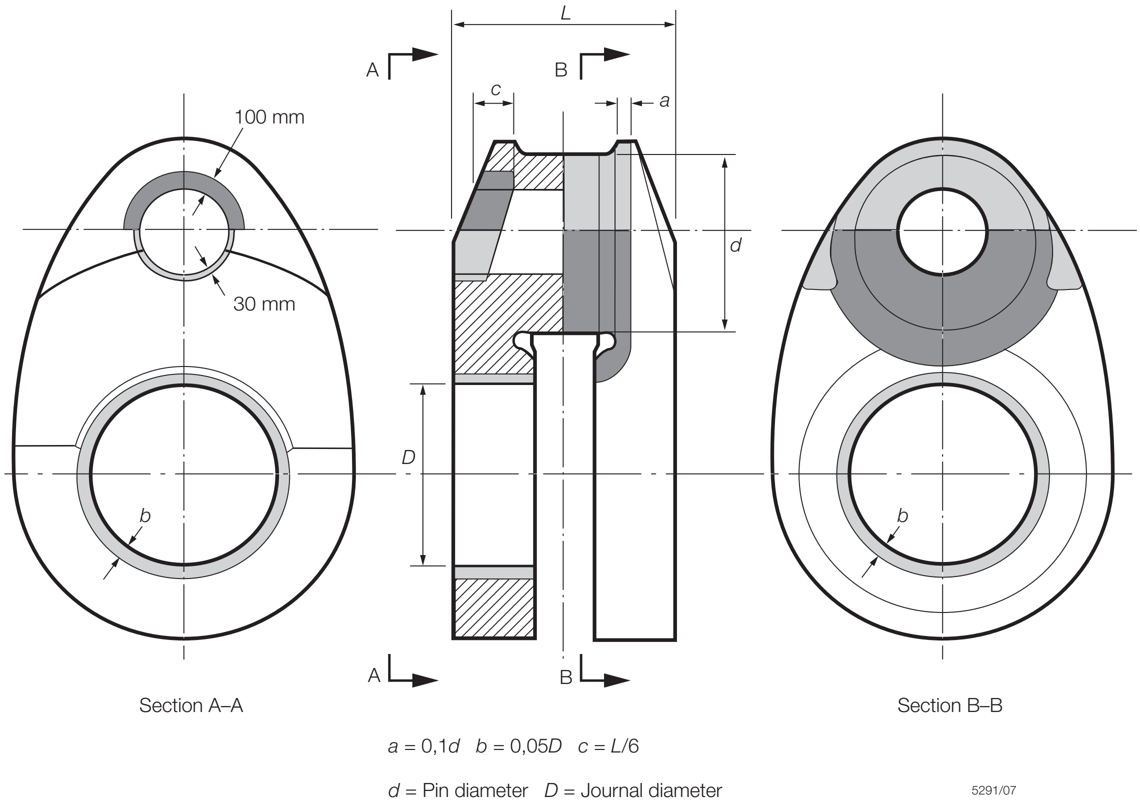


Fig. 4.4.2 Ultrasonic examination acceptance levels

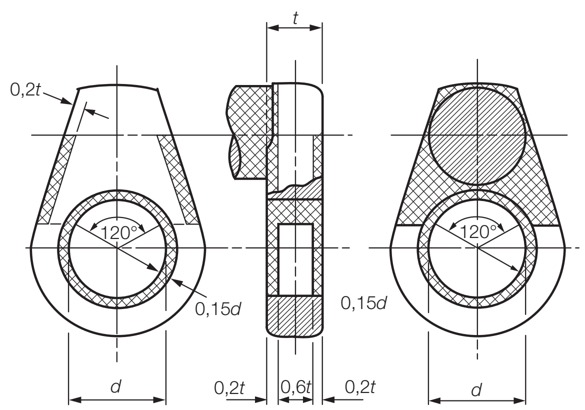


Fig. 4.4.3
Areas of semi-built crank throws to which weld repairs are not permitted

■ *Section 5* Castings for propellers

5.1 Scope

5.1.1 This Section gives the requirements for steel castings for one-piece propellers and separately cast blades and hubs for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers, azipods and azimuth thrusters. The requirements for copper alloy propellers, blades and hubs are given in Ch 9,1.

5.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and Ch 4,1 as well as the requirements of this Section.

5.1.3 Full details of the manufacturer's specification are to be submitted for approval. These should include the chemical composition, heat treatment, mechanical properties, micro-structure and repair procedures.

5.1.4 Special requirements are given for castings which are intended for ice service in Table 4.5.2.

5.2 Chemical composition

5.2.1 The chemical composition of ladle samples is to comply with the approved specification, *see* 5.1.3.

5.2.2 Typical cast steel propeller alloys are given in Table 4.5.1.

5.3 Heat treatment

5.3.1 Martensitic stainless steel castings are to be austenitised, quenched and tempered in accordance with the approved specification, *see* 5.1.3.

5.3.2 Austenitic stainless steel castings are to be solution treated in accordance with the approved specification, *see* 5.1.3.

5.4 Mechanical tests

5.4.1 The test material is to be cast integral with the boss of propeller castings, or with the flange of separately cast propeller blades. Alternatively, the test material may be attached on blades in an area between 0,5 and 0,6R, where R is the radius of the propeller.

5.4.2 The test material is not to be removed from the casting until final heat treatment has been carried out. Removal is to be by non-thermal procedures.

5.4.3 At least one tensile test and for the martensitic stainless steel grades one set of three Charpy V-notch impact tests are to be made on material representing each casting. The results are to comply with the requirements of Table 4.5.2 or the approved specification.

5.4.4 As an alternative to 5.4.3, where a number of small propeller castings of about the same size, and less than 1 m in diameter, are made from one cast and heat treated together in the same furnace, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

5.4.5 Separately cast test bars may be used subject to prior approval of the Surveyor. Test bars must be cast from the same heat, or heats, and must also be heat treated with castings they represent.

5.5 Non-destructive examination

5.5.1 On completion of machining and grinding, the whole surface of each casting is to be examined in accordance with Ch 9,1.8.

5.5.2 When appropriate, magnetic particle inspection may be used in lieu of liquid penetrant testing.

5.5.3 Castings are to be free from cracks and hot tears.

Table 4.5.1 Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo Max. (%) (*see* Note)	Ni (%)
Martensitic (12Cr 1Ni)	0,15	2,0	11,5–17,0	0,5	Max. 2,0
Martensitic (13Cr 4Ni)	0,06	2,0	11,5–17,0	1,0	3,5–5,0
Martensitic (16Cr 5Ni)	0,06	2,0	15,0–17,5	1,5	3,5–6,0
Austenitic (19Cr 11Ni)	0,12	1,6	16,0–21,0	4,0	8,0–13,0

NOTE
Minimum values are to be in accordance with the agreed specification or recognised National or International Standards.

Table 4.5.2 Typical mechanical properties for steel propeller castings

Alloy type	Yield stress or, 0,2% proof stress minimum, N/mm^2	Tensile strength minimum N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests J minimum (*see* Notes 1 and 2)
Martensitic (12Cr 1Ni)	440	590	15	30	20
Martensitic (13Cr 4Ni)	550	750	15	35	30
Martensitic (16Cr 5Ni)	540	760	15	35	30
Austenitic (19Cr 11Ni)	180 (*see* Note 3)	440	30	40	—

NOTES
1. When a general service notation **Ice Class 1AS, 1A, 1B or 1C** is required, the tests are to be made at –10°C.
2. For general service or where the notation **Ice Class 1D** is required, the tests are to be made at 0°C.
3. $R_{p1,0}$ value is 205 N/mm^2.

5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with 1.9 and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g., by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours.

5.6.3 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in zone A and will only be allowed after special consideration.

5.6.4 Defects in severity zone B that are not deeper than $t/40$ mm (t is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity zone C.

5.6.6 Welds having an area of less than 5 cm^2 are to be avoided. The maximum surface area of repairs is to be in accordance with Table 9.1.4 in Chapter 9.

5.6.7 Welding is to be in accordance with the approved specification, *see* 5.1.3.

5.6.8 After weld repair, the propeller or blade is to be heat treated in such fashion as will minimise the residual stresses. For martensitic stainless steels, this will involve full heat treatment as specified in the approved specification.

5.6.9 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

5.6.10 All welds are to be inspected by the appropriate NDE method, *see* 1.7.

5.7 Identification

5.7.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:
(a) Identification mark which will enable the full history of the item to be traced.
(b) Type of steel, this should include or allow identification of the chromium and nickel contents.
(c) LR or Lloyd's Register and the abbreviated name of Lloyd's Register's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) LR certificate number.
(f) Skew angle, if in excess of 25°.
(g) Ice class symbol, where applicable.
(h) Date of final inspection.

5.8 Certification of materials

5.8.1 In addition to the requirements in Ch 4,1.11, the manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:
(a) Description of casting with drawing number.
(b) Diameter, number of blades, pitch, direction of turning.
(c) Skew angle, if in excess of 25°.
(d) Final mass.
(e) Vessel identification, where known.

■ *Section 6*
Castings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

6.1.2 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases, the specified minimum tensile strength is not to exceed 600 N/mm^2.

6.1.3 Castings which comply with these requirements are acceptable for liquefied gas piping systems where the design temperature is not lower than 0°C. Where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required, the castings are to comply with the requirements of Section 7 or 8.

6.2 Chemical composition

6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.6.1.

6.3 Heat treatment

6.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.

6.4 Mechanical tests

6.4.1 A tensile test is to be made on material representing each casting, unless a batch testing procedure has been agreed, *see* 1.6.

6.4.2 The tensile test is to be carried out at ambient temperature, and unless agreed otherwise with the Surveyor, the results are to comply with the requirements of Table 4.6.2.

Table 4.6.1 Chemical composition of steel castings for boilers, pressure vessels and piping systems

Type of steel	Chemical composition %										
	C max.	Si max.	Mn	S max.	P max.	Residual elements					
Carbon-manganese	0,25	0,60	0,50-1,20	0,040	0,040	Cr 0,30 max. Mo 0,15 max. Cu 0,30 max. Ni 0,40 max. Total 0,80 max.					
						Cr	Mo	V	Residual elements Cr	Cu	Ni
$^{1}/_{2}$ Mo	0,20	0,60	0,50–1,00	0,040	0,040	—	0,45-0,65	—	0,30 max.	0,30 max.	0,40 max.
1 Cr $^{1}/_{2}$ Mo	0,20	0,60	0,50-0,80	0,040	0,040	1,00-1,50	0,45-0,65	—	—	0,30 max.	0,40 max.
2 $^{1}/_{4}$ Cr1 Mo	0,18	0,60	0,40-0,70	0,040	0,040	2,00-2,75	0,90-1,20	—	—	0,30 max.	0,40 max.
$^{1}/_{2}$ Cr $^{1}/_{2}$ Mo $^{1}/_{4}$ V	0,10–0,15	0,45	0,40-0,70	0,030	0,030	0,30-0,50	0,40-0,60	0,22-0,30	—	0,30 max.	0,30 max.

Table 4.6.2 Mechanical properties for acceptance purposes: steel castings for boilers, pressure vessels and piping systems

Type of steel	Yield stress minimum N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
Carbon-manganese	275	485-655	22	25
$^{1}/_{2}$Mo	260	460-590	18	30
1Cr$^{1}/_{2}$Mo	280	480-630	17	20
2$^{1}/_{4}$ Cr1 Mo	325	540-630	17	20
$^{1}/_{2}$Cr$^{1}/_{2}$Mo$^{1}/_{4}$V	295	510-660	17	20

6.4.3 Where it is proposed to use a carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and reduction of area may be obtained by interpolation.

6.4.4 Carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2, but not exceeding 520 N/mm^2, may be accepted provided that details of the proposed specification are submitted for approval.

6.5 Non-destructive examination

6.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally as agreed between the manufacturer, purchaser and Surveyor.

6.6 Mechanical properties for design purposes

6.6.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 100°C and higher are given in Table 4.6.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 4.6.3.

6.6.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each casting or each batch of castings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

6.6.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 4.6.4 and may be used for design purposes.

Table 4.6.3 Mechanical properties for design purposes (*see* 6.6.1)

Type of steel	Nominal minimum lower yield or 0,2% proof stress N/mm^2										
	Temperature °C										
	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese	225	214	201	186	163	156	152	—	—	—	—
$^1/_2$Mo	242	236	226	207	186	175	169	158	145	136	126
1Cr$^1/_2$Mo	240	—	212	—	196	—	184	—	160	—	117
2$^1/_4$Cr1 Mo	323	312	305	296	290	280	273	258	240	211	180
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	264	—	244	—	230	—	214	—	194	—	144

Table 4.6.4 Mechanical properties for design purposes (*see* 6.6.3)**: estimated average stresses to rupture in 100,000 hours (N/mm^2)**

Temperature °C	Type of steel			
	$^1/_2$Mo	1Cr$^1/_2$Mo	2$^1/_4$Cr1Mo	$^1/_2$Cr$^1/_2$Mo$^1/_4$V
430	308	—	—	—
440	276	—	—	—
450	245	—	222	277
460	212	—	199	237
470	174	236	177	206
480	133	186	156	181
490	103	148	139	159
500	84	120	124	140
510	71	100	111	124
520	60	84	99	109
530	—	70	—	96
540	—	58	—	85
550	—	—	—	75
560	—	—	—	66

■ *Section 7*

Ferritic steel castings for low temperature service

7.1 Scope

7.1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels, intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

7.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.7.1. Carbon-manganese steels are to be made by fine grain practice.

7.3 Heat treatment

7.3.1 Castings are to be supplied:

(a) normalised; or

(b) normalised and tempered; or

(c) quenched and tempered.

7.4 Mechanical tests

7.4.1 One tensile test and one set of three Charpy V-notch impact test specimens are to be prepared from material representing each casting or batch of castings.

7.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the appropriate requirements given in Table 4.7.2.

7.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.7.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedure.

7.5 Non-destructive examination

7.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

Table 4.7.1 Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition % C max.	Si max.	Mn	S max.	P max.	Ni	Residual elements max.
Carbon-manganese	0,25	0,60	0,70-1,60	0,030	0,030	0,80 max.	Cr 0,25 Cu 0,30 Mo 0,15 V 0,03 Total 0,60
$2^1/_4$Ni	0,25	0,60	0,50-0,80	0,025	0,030	2,00-3,00	
$3^1/_2$Ni	0,15	0,60	0,50-0,80	0,020	0,025	3,00-4,00	

Table 4.7.2 Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction or area % minimum	Charpy V-notch impact test: Test temperature °C	Charpy V-notch impact test: Average energy J minimum
Carbon-manganese	400 430 460	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	–60 (*see* Note)	27
$2^1/_4$Ni	490	275	490-640	20	35	–70	34
$3^1/_2$Ni	490	275	490-640	20	35	–95	34

NOTE
The test temperature for carbon-manganese steels may be 5°C below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

■ *Section 8* Stainless steel castings

8.1 Scope

8.1.1 This Section gives the requirements for castings in austenitic and duplex stainless steels for machinery, marine structures, piping systems in ships for liquefied gases, and in bulk chemical tankers.

8.1.2 Austenitic stainless steels castings are suitable for applications where the lowest design temperature is not lower than –165°C.

8.1.3 Duplex stainless steels castings are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels castings below 0°C will be subject to special consideration.

8.1.4 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 4.8.1.

8.3 Heat treatment

8.3.1 Austenitic stainless steel castings are to be solution treated, at a temperature of not less than 1000°C and cooled rapidly in water.

8.3.2 Duplex stainless steels castings are to be solution treated at a temperature of not less that 1100°C and cooled rapidly in water.

8.4 Mechanical tests

8.4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

8.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the requirements given in Table 4.8.2.

Table 4.8.1 Chemical composition of stainless steel castings

Type of steel	Chemical composition %								
	C	Si	Mn	S	P	Cr	Mo	Ni	Others
Austenitic									
304L	0,03	0,20-1,5	0,50-2,0	0,040		17,0-21,0	—	8,0–12,0	—
304	0,08						—	8,0–12,0	—
316L	0,03						2,0–3,0	9,0–13,0	—
316	0,08						2,0–3,0	9,0–13,0	—
317	0,08						3,0–4,0	9,0–12,0	—
347 (*see* Note 1)	0,06						—	9,0–12,0	Nb ≥ 8 x C ≤ 0,90
Duplex									
UNS J 92205 (*see* Note 3)	0,03	1,00	1,50	0,020	0,035	21,0–23,0	2,5–3,5	4,5–6,5	N 0,15–0,20 Cu 1,00

NOTES
1. When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0,08% and the maximum niobium may be 1,00%.
2. Where a single value is shown (and not a range of values), the value is to be taken as maximum.
3. The grade UNS J 92205 is the cast equivalent of UNS S 31803.

Table 4.8.2 Mechanical properties for acceptance purposes: stainless steel castings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
Austenitic						
304L	430	215	26	40	–196	41
304	480	220				
316L	430	215	26	40	–196	41
316	480	220				
317	480	240				
347	480	215	22	35	–196	41
Duplex						
UNS J 92205 (*see* Note)	600	420	20	35	0	41

NOTE
The grade UNS J 92205 is the cast equivalent of UNS S 31803.

8.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.8.2. One individual value may be less than the required average value, provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

8.5 Corrosion tests

8.5.1 Where corrosive conditions are anticipated in service, for grades 304, 316 and 317, intergranular corrosion tests are required in accordance with Ch 2,8.1. Such tests may also be required for grades 304L, 316L and 347.

8.5.2 Where corrosive conditions are anticipated in service, for duplex stainless grades pitting corrosion tests are required in accordance with ASTM G48 Method C. For duplex stainless steel grade UNS J 92205 the test temperature is to be 20°C. Following the test, no pitting corrosion is to be observed at 20x magnification. The use of a weight loss method may be accepted subject to special consideration.

8.6 Non-destructive examination

8.6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

■ *Section 9* Steel castings for container corner fittings

9.1 General

9.1.1 This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

9.1.2 The castings are to be made in foundries approved by LR. These foundries are also to be specially approved for the manufacture of container corner castings. In order to comply with these requirements, the manufacturer is required to verify that the casting soundness, mechanical properties, weldability and dimensional tolerances required by this Section and the manufacturing specification are met.

9.1.3 Castings may be released on the basis of an LR survey or, alternatively, the manufacturer may be approved by means of a Quality Assurance Scheme as detailed in Ch 1,2.

9.2 Chemical composition

9.2.1 Chemical analysis is to be carried out on each cast.

9.2.2 The chemical composition of the ladle samples is to comply with the limits given in Table 4.9.1.

9.2.3 The carbon equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}\ (\%)$$

must not exceed 0,45 per cent.

9.3 Heat treatment

9.3.1 Castings are to be supplied either:
(a) normalised; or
(b) water or oil quenched and tempered at a temperature of not less than 550°C.

9.4 Mechanical tests

9.4.1 At least one tensile test is to be made on each batch of castings, using separately cast test bars which are to be from the same cast and heat treatment lot as the castings they represent.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	220 N/mm^2 min.
Tensile strength	430–600 N/mm^2
Elongation on $\sqrt{S_o}$	25% min.
Reduction of area	40% min.

9.4.3 Impact tests are not required on all casts, but may be required on a random basis at the discretion of the Surveyor.

9.4.4 When required, the impact test specimens are to be tested in accordance with Ch 1,4.5 and Ch 2,3.2. In general, tests are to be made at a temperature of –20°C and the minimum average energy obtained is to be 27J.

9.5 Non-destructive examination

9.5.1 Ultrasonic or radiographic testing is to be carried out, in accordance with 1.7.10 or 1.7.11 respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser.

Table 4.9.1 Chemical composition of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	Al acid soluble min. (*See* Notes)	Cr + Ni + Cu + Mo max.
0,20	0,90 to 1,50	0,50	0,035	0,035	0,25	0,30	0,20	0,08	0,015	0,70

NOTES
1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.
2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

9.6 Repair of defects

9.6.1 Minor defects may be removed by grinding provided that the allowable minus tolerance is not exceeded.

9.6.2 Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:

(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,
(b) the casting is to be preheated to 80–100°C,
(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,
(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,
(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.

9.7 Identification

9.7.1 Each casting is to be clearly marked by the manufacturer with at least the following:

(a) manufacturer's name or trade mark,
(b) cast number or identification number which will enable the full history of the casting to be traced.

9.7.2 Where the casting has been inspected and found acceptable it is to be marked with the Surveyor's personal stamp.

9.7.3 The markings may be stamped or cast on the inner surface of the casting.

9.8 Certification of materials

9.8.1 For each consignment an LR certificate, *see* Ch 1,3.1, is to be issued for castings made under LR survey or alternatively a manufacturer's certificate is to be issued containing at least the following:

(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.

See Ch 1,3.1, for manufacturers approved under a Quality Assurance Scheme.

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel forgings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

1.1.2 When required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, steel forgings which comply with National or proprietary specifications, may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter, or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Normalised forgings with mass up to 1000 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same steel-making heat, heat treated together and with a total mass not exceeding 6 tonnes.

1.1.5 Quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same steel-making heat, heat treated together in the same furnace and with a total mass not exceeding 3 tonnes.

1.1.6 A batch testing procedure may also be used for hot rolled bars, *see* 3.4.3.

1.1.7 Where small forgings are produced in large quantities, or where forgings of the same type are produced in regular quantities, alternative survey procedures in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Forgings are to be made at works which have been approved by Lloyd's Register (hereinafter referred to as LR). The steel used, is to be manufactured in accordance with the requirements of Ch 3,1.4.

1.2.2 When forgings are made directly from ingots, or from blooms or billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

1.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

1.2.4 The forgings are to be gradually and uniformly hot worked and are to be formed as closely as possible to the finished shape and size. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

1.2.5 For certain components, such as crankshafts, where grain flow is required in the most favourable direction, having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by LR. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

1.2.6 The reduction ratio (reduction of area expressed as a ratio) is to be calculated with reference to the average cross-sectional area of the ingot or continuously cast material, where appropriate. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

1.2.7 For components forged directly from ingots or from forged blooms or billets, and in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than 3:1.

1.2.8 For forgings made from rolled billets, or where fibre deformation has taken place in more than one direction, the reduction ratio is not to be less than 4:1.

1.2.9 Where rolled bars are used as a substitute for forgings and the requirements of 1.2.2 are not complied with, the reduction ratio is to be not less than 6:1.

1.2.10 Where the length of any section of a shaft forging is less than its diameter (e.g., a collar), the reduction ratio is to be not less than half that given in 1.2.7, 1.2.8 or 1.2.9 respectively.

1.2.11 Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the disc is to be not more than one-half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disc is to be not more than one-third of the length of the original piece.

1.2.12 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than one-half of the thickness of the prepared hollow piece from which it was formed. Where this is not practicable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

1.2.13 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognised good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required, *see* 4.2.4.

1.2.14 Where two or more forgings are joined by welding to form a composite component, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests may be required.

1.3 Quality

1.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.4 Chemical composition

1.4.1 All forgings are to be made from killed steels, and the chemical composition of ladle samples is to comply with the requirements detailed in subsequent Sections in this Chapter. Where general overall limits are specified, the chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

1.4.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.4.3 For alloy steel forgings, the chemical composition of ladle samples is to generally comply with the following overall limits and the requirements of the approved specifications:

Carbon	0,45% max.
Silicon	0,45% max.
Manganese	0,30% min.
Sulphur	0,035% max.
Phosphorus	0,035% max.
Copper	0,30% max.

And at least one of the following elements is to comply with the minimum content:

Chromium	0,40% min.
Molybdenum	0,15% min.
Nickel	0,40% min.

The contents of all alloying elements and significant impurities detailed in the specification are to be reported.

1.5 Heat treatment

1.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties. Acceptable heat treatment procedures are to be such as to avoid the formation of hair-line cracks and are detailed in Sections 2 to 9.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control. The furnace dimensions are to be such as to allow all the steel forgings to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. Sufficient thermocouples are to be connected to the steel forging(s) in the furnace to show that the temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the steel-making heat, the heat treatment temperature, time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. Alternative procedures are to be approved by LR's Materials and NDE Department.

1.5.3 Where forgings are to be quenched and tempered and cannot be hot worked close to size and shape, they are to be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.4 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated.

1.5.5 If any straightening operation is performed after the final heat treatment, consideration should be given to a subsequent stress relieving heat treatment in order to avoid the possibility of harmful residual stresses.

1.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer will be required to demonstrate by tests that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

1.5.7 Where induction hardening or nitriding is to be carried out after machining, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

1.5.8 Where carburising is to be carried out after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalising and tempering) to a condition suitable for subsequent machining and carburising.

1.5.9 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, thermocouple location, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

1.6 Test material

1.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging, except in the case of small forgings which are batch tested, *see* 1.6.4.

1.6.2 Where a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging, *see* 2.4.2.

1.6.3 Except for components which are to be carburised, test material is not to be cut from a forging until the heat treatment detailed in Sections 2 to 9 has been completed. The testing procedure for components which are to be carburised is to be in accordance with the details given in Section 5.

1.6.4 Where a number of small forgings of about the same size are made from one cast and heat treated together in the same furnace, batch testing procedures (*see* 1.1.4) may be adopted using one of the forgings for test purposes, or alternatively using separately forged test samples. These test samples are to have a forging reduction similar to that used for the forgings which they represent. They are to be properly identified and heat treated together with the forgings.

1.7 Mechanical tests

1.7.1 Specimens for mechanical tests are to be prepared as required by Sections 2 to 9.

1.7.2 Test specimens are normally to be cut with their axes mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(a) for thickness or diameter ≤ 50 mm, the axis is to be at the mid-thickness or the centre of the cross-section;

(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface;

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12,5 mm to any heat treated surface. For impact testing, this requirement is to apply to the complete test piece.

1.7.4 Tensile test specimens are to be machined to the dimensions detailed in Chapter 2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area.

1.7.5 Impact test specimens are to be prepared in accordance with the requirements of Chapter 2.

1.7.6 The procedures used for the tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.7.7 Hardness tests, preferably of the Brinell type, are to be carried out when specified in subsequent Sections in this Chapter.

1.8 Visual and non-destructive examination

1.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores.

1.8.2 Forgings are to be examined in the condition for final delivery. Surfaces are to be clean and free from dirt, grease, paint, etc. Black forgings are to be suitably descaled by either shotblasting or flame descaling methods.

1.8.3 All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, dye penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. All tests are to be carried out in accordance with the requirements of Ch 1,5.

1.8.5 Magnetic particle and dye penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

1.8.6 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Nonlinear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

1.8.7 Acceptance standards for defects found by visual or non destructive examinations are to be in accordance with any specific requirements of the approved plan, and with equivalence to any additional requirements of this Chapter. In all cases they are to be to the satisfaction of the Surveyor.

1.8.8 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Scanning is to take into account near surface examination. Unless otherwise agreed, examinations are to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.9 If the forging is supplied in the black condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

1.8.10 In the circumstance detailed in either 1.8.8 or 1.8.9, the manufacturer is to provide the Surveyor with a signed report confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects.

1.8.11 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.8.12 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

1.8.13 When required by the conditions of approval for surface hardened forgings (*see* 1.5.6) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination (as appropriate to the material). At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for review by the Surveyors prior to the commencement of the proposed rectification. A report and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Repair welding is not permitted for crankshafts or similar rotating components.

1.9.4 Where fabrication welding is involved, *see* 1.2.14, any repair of defects is to be carried out in accordance with the approved welding procedure.

1.9.5 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging. The records are to be presented to the Surveyor on request.

1.9.6 Non-open indications evaluated as segregation are acceptable.

1.10 Identification

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast, forging process and heat treatment batch, and the Surveyor is to be given full facilities for so tracing the castings when required.

1.10.2 Forgings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all forgings which have been accepted:

(a) Identification number, cast number or other marking which will enable the full history of the forging to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

1.10.3 Modified arrangements for the identification of small forgings manufactured in large numbers, as with closed-die forgings may be agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each forging or batch of forgings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of forgings and steel quality.
(c) Identification number.
(d) Steel-making process, cast number and chemical analysis of ladle samples.
(e) General details of heat treatment.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 As a minimum, the chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

1.11.4 Where applicable, the manufacturer is also to provide a signed report regarding ultrasonic examination as required by 1.8.8, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

1.11.5 When steel is not produced at the works at which it is forged, a certificate is to be supplied by the steelmaker stating the process of manufacture, cast number and the chemical composition of ladle samples. The works at which the steel was produced is to have been approved by LR, *see* 1.4.3.

■ *Section 2*
Forgings for ship and other structural applications

2.1 Scope

2.1.1 This Section gives the specific requirements for carbon-manganese steel forgings intended for ship and other structural applications such as rudder stocks, pintles, etc.

2.1.2 Where it is proposed to use an alloy steel, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval, *see* 1.4.3.

2.2 Chemical composition

2.2.1 For forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component, or are to be weld cladded or may be subject to weld repair in service, the chemical composition of ladle samples is to comply with the following:

Carbon	0,23% max.
Silicon	0,45% max.
Manganese 0,30–1,50% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment	
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

For samples from forgings, the carbon content is not to exceed 0,26 per cent.

2.2.2 It is recommended that forgings for rudder stocks, pintles and rudder coupling bolts comply with 2.2.1 in order to obtain satisfactory weldability for any future repairs by welding in service.

2.2.3 For forgings not intended for welding the carbon content may be 0,65 per cent max., *see* 3.2.1.

2.3 Heat treatment

2.3.1 Carbon-manganese steel forgings are to be:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C.
(d) quenched and tempered.

2.3.2 Alloy steel forgings are to be quenched and then tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties are to be agreed by LR.

2.4 Mechanical tests

2.4.1 At least one tensile specimen is to be taken from each forging or batch of forgings.

2.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

2.4.3 Unless otherwise agreed between the manufacturer and the Surveyor, the test specimens are to be cut in a longitudinal direction.

2.4.4 The results of all tensile tests are to comply with the requirements given in Table 5.2.1 appropriate to the specified minimum tensile strength. Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5.2.1, and intermediate values may be obtained by interpolation. *See* 2.4.6 for rudder stocks, pintles, and rudder coupling keys and bolts.

2.4.5 For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

2.4.6 For rudder stocks, pintles, and rudder coupling keys and bolts, the minimum specified yield strength is not to be less than 200 N/mm^2, *see* Table 13.2.4 in Pt 3, Ch 13.

2.4.7 Impact tests are required for rudder stocks to be fitted to vessels which have an ice class notation. The tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

2.5 Non-destructive examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or dye penetrant testing where appropriate).

2.5.2 Surface inspections are to be carried out in the zones I and II as indicated in Fig. 5.2.1.

2.5.3 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm^2. The area is to be taken in the most unfavourable location relative to the indication being evaluated.

2.5.4 The allowable number and size of indications in the reference area is given in Table 5.2.2.

2.5.5 Volumetric inspection is to be carried out by ultrasonic testing using the contact method.

2.5.6 Ultrasonic testing is to be carried out on rudder stocks having a finished diameter of 200 mm or greater.

2.5.7 Ultrasonic testing is to be carried out in the zones I to III as indicated in Fig. 5.2.2. Areas may be upgraded to a higher zone at the discretion of the Surveyor.

Table 5.2.1 Mechanical properties for ship and other structural applications

Steel type	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	180	360-480	28	20	50	35
	200	400-520	26	19	50	35
	220	440-560	24	18	50	35
	235	470-590	23	17	45	35
	240	480-600	22	16	45	30
	260	520-640	21	15	45	30
	280	560-680	20	14	40	27
	300	600-750	18	13	40	27
	320	640-790	17	12	40	27
	340	680-830	16	12	35	24
	360	720-870	15	11	35	24
	380	760-910	14	10	35	24
Alloy	350	550-570	20	14	50	35
	400	600-750	18	13	50	35
	450	650-800	17	12	50	35

Table 5.2.2 Steel forgings surface inspection

Inspection zone	Maximum number of indications	Type of indication	Maximum number each type	Maximum dimension, mm
I	3	Linear Non-linear Aligned	0, *see* Note 3 0, *see* Note	— 3,0 —
II	10	Linear Non-linear Aligned	3, *see* Note 7 3, *see* Note	3,0 5,0 3,0

NOTE
Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g., main bearing bolts, connecting rod bolts, crosshead bearing bolts and cylinder cover bolts.

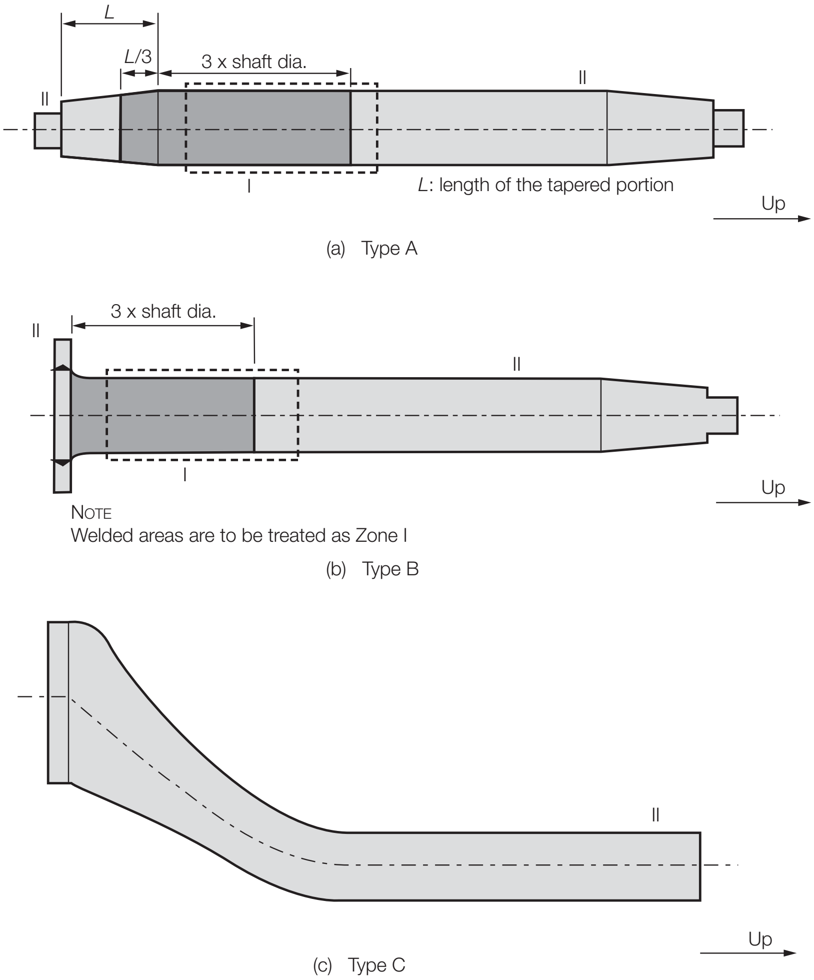


Fig. 5.2.1 Inspection zones for magnetic particle/dye penetrant testing on rudder stocks

2.5.8 Ultrasonic acceptance criteria are shown in Table 5.3.4, alternatively *see* Ch 1,5.

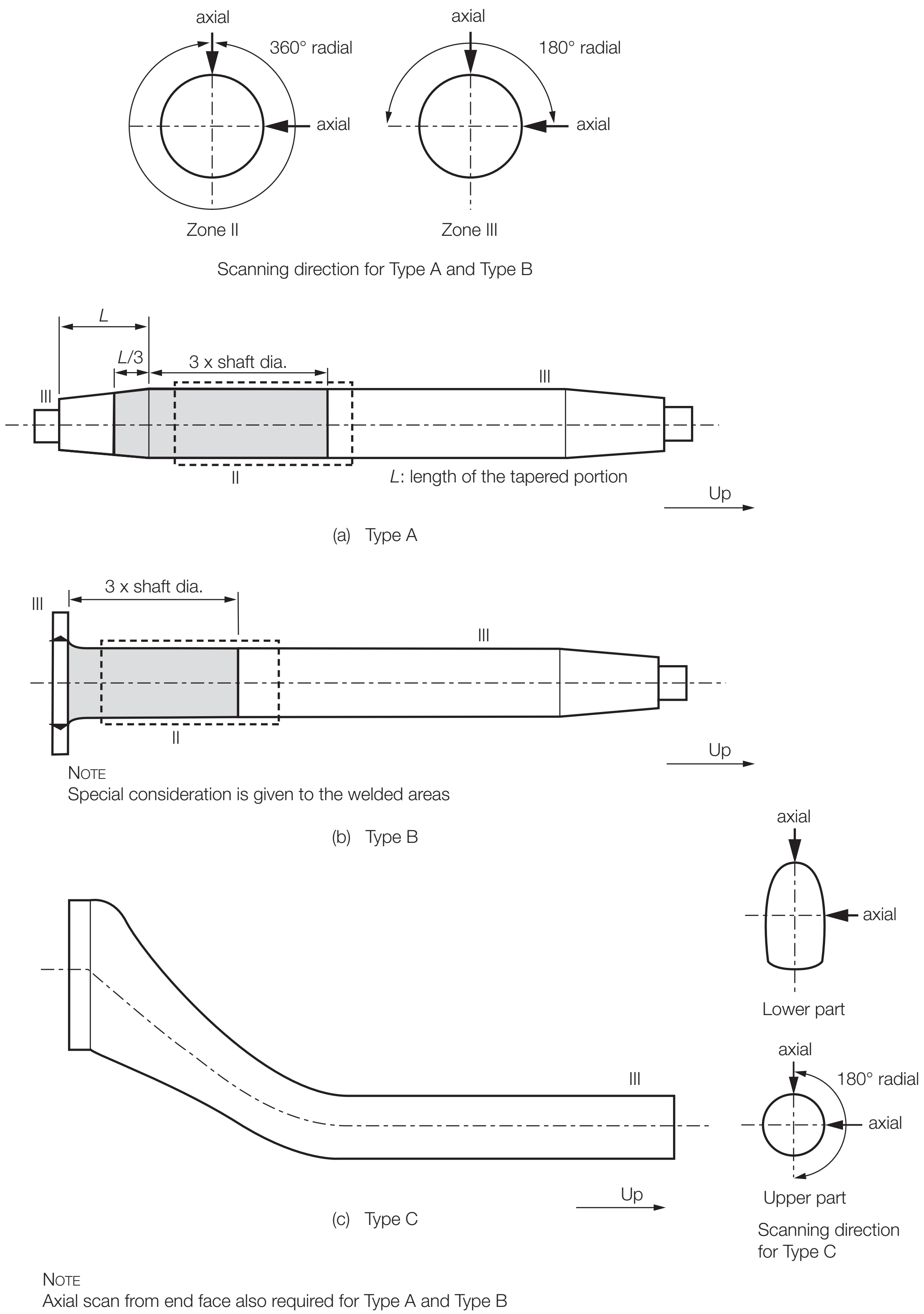


Fig. 5.2.2 Inspection zones for ultrasonic testing on rudder stocks

■ *Section 3* Forgings for shafting and machinery

3.1 Scope

3.1.1 Detailed in this Section are the requirements for carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) and for other forgings is not to exceed 1100 N/mm^2 (1100–1300 N/mm^2 acceptance range).

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples for carbon and carbon-manganese steels is to comply with the following overall limits:

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30–1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

3.2.2 For alloy steels, *see* 1.4.3.

3.2.3 For forgings to which structural items are to be attached by welding, or which are intended for parts of a fabricated component, are to be of weldable quality, *see* 2.2.1.

3.3 Heat treatment

3.3.1 Forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.
The tempering temperature is to be not less than 550°C.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on each forging, or each batch of forgings. Impact tests are not required except on screwshafts for ice service, *see* 3.4.12.

3.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, a tensile test is to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

3.4.3 A batch testing procedure may be used for hot rolled bars not exceeding 250 mm diameter, which are intended for the manufacture (by machining operations only) of straight shafting, bolts, studs and other machinery components of similar shape. A batch is to consist of either:
(a) material from the same piece provided that where this is cut into individual lengths, these are all heat treated together in the same furnace; or
(b) bars of the same diameter and cast, heat treated together in the same furnace and with a total mass not exceeding 2,5 tonnes.

3.4.4 The test specimens are to be taken in the longitudinal direction but, at the discretion of the manufacturer and if agreed by the Surveyor, alternative directions or positions as shown in Figs. 5.3.1 to 5.3.3 may be used.

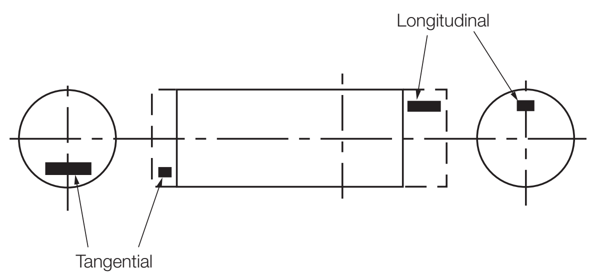


Fig. 5.3.1
Directions and positions of test specimens

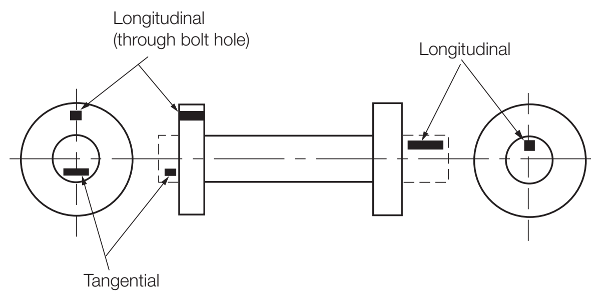


Fig. 5.3.2
Directions and positions of test specimens

3.4.5 For carbon-manganese steels, Table 5.3.1 gives the minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate values for other specified minimum tensile strengths should be calculated by interpolation.

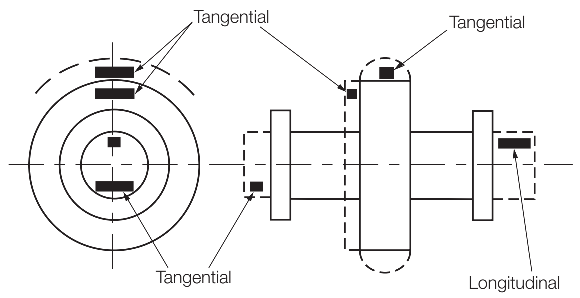


Fig. 5.3.3
Directions and positions of test specimens

3.4.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.1, except that for main propulsion shafting forgings the specified minimum tensile strength is to be not less than 400 N/mm^2 (400–520 N/mm^2 acceptance range) and not greater than 600 N/mm^2 (600–750 N/mm^2 acceptance range) *see* shaded area of Table 5.3.1.

3.4.7 The results of all tensile tests are to comply with the requirements given in Table 5.3.1 appropriate to the specified minimum tensile strength.

3.4.8 The minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels in alloy steel forgings are given in Table 5.3.2.

Table 5.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
360–480	180	28	20	50	35
400–520	200	26	19	50	35
440–560	220	24	18	50	35
470–590	235	23	17	45	35
480–600	240	22	16	45	30
520–640	260	21	15	45	30
560–680	280	20	14	40	27
600–750	300	18	13	40	27
640–790	320	17	12	40	27
680–830	340	16	12	35	24
700–850 [2]	350	15	11	35	24
720–870 [2]	360	15	11	35	24
760–910 [2]	380	14	10	35	24

NOTES
1. For main propulsion shafting forgings, the specified minimum tensile strength is to be between 400 and 600 N/mm^2 (shaded area of Table) *see* 3.4.6.
2. Where the specified minimum tensile strength exceeds 700 N/mm^2, forgings are to be supplied only in the quenched and tempered condition.

Table 5.3.2 Mechanical properties for acceptance purposes: alloy steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
600–750	420	18	14	50	35
650–-800	450	17	13	50	35
700–850	480	16	12	45	30
750–900	530	15	11	45	30
800–950	580	14	10	40	27
850–1000	630	13	9	40	27
900–1100	690	13	9	40	27
950–1150	750	12	8	35	24
1000–1200	810	12	8	35	24
1050–1250	870	11	7	35	24
1100–1300	930	11	7	35	24

NOTE
For main propulsion shafting forgings, the minimum specified tensile strength is not to exceed 800 N/mm^2, *see* 3.4.9 (shaded area of Table).

3.4.9 Forgings in alloy steels may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.2, and minimum yield stress, elongation and reduction of area, obtained by interpolation, except that for main propulsion shafting forgings the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) *see* shaded area of Table 5.3.2.

3.4.10 The results of all tensile tests are to comply with the requirements given in Table 5.3.2 appropriate to the specified minimum tensile strength.

3.4.11 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 < 900	100
≥900	120

3.4.12 For screwshafts intended for ships with the notation **Ice Class 1AS** or **1A** and where the connection between the propeller and the screwshaft is by means of a key, a set of three Charpy V-notch impact tests (longitudinal test) is to be made on material from the propeller end of each shaft. The tests are to be carried out at –10°C and the average energy value is to be not less than 20 J.

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than 100 mm), on all connecting rod forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
  - Cylinder covers
  - Crossheads
  - Main bearings
  - Connecting rod bearings
  - Propeller blade fastening bolts
  - Crankpin bolts
  - Tie rod bolts
  - Additionally, bolts for engine bore diameters of less than 400 mm but having a minimum diameter 50 mm or greater (which are subjected to dynamic stress), are also to be subjected to surface examinations.

3.5.2 The areas to be tested by magnetic particle or dye penetrate testing are shown in Fig. 5.3.4 and Fig. 5.3.5. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested.

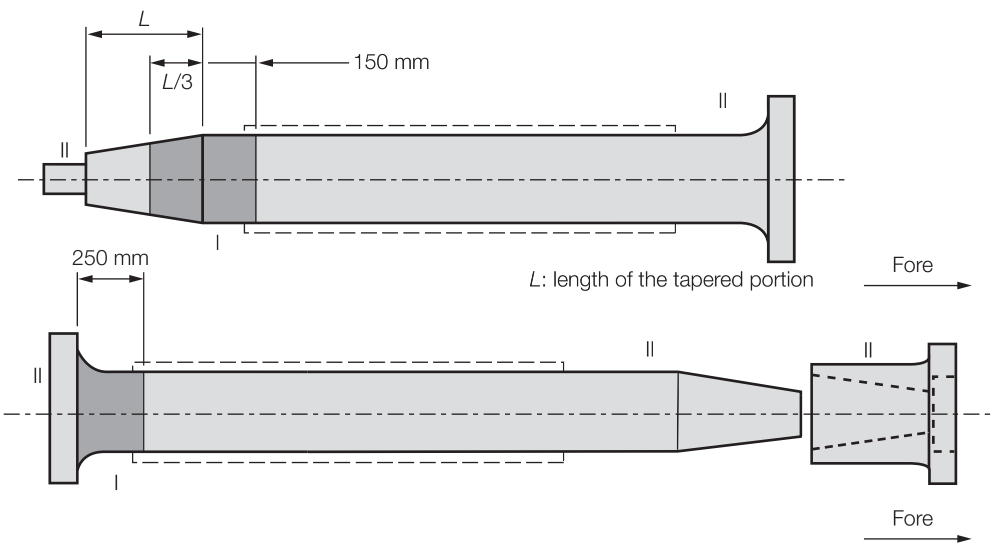
3.5.3 Surface inspection acceptance criteria are to be in accordance with 2.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

3.5.4 Ultrasonic testing is to be carried out in accordance with 2.5 on the following items:

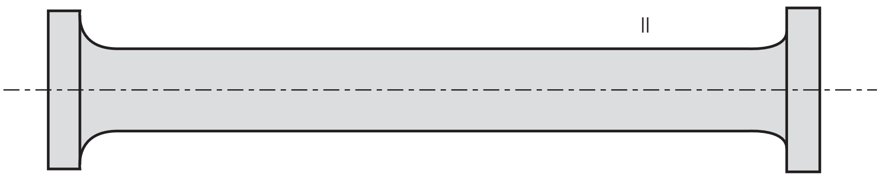
(a) Shafts having a finished diameter of 200 mm or larger when intended for main propulsion or other essential services.
(b) All piston crowns and cylinder covers.
(c) Piston rods and connecting rods for engines having a bore diameter greater than 400 mm.

The areas to be tested are shown in Fig. 5.3.6 and Fig. 5.3.7. Areas of other components not shown in these drawings are to be agreed with the Surveyor.

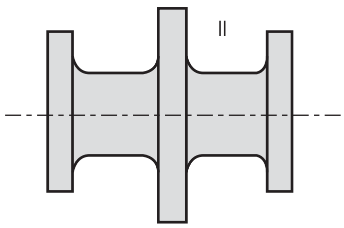
3.5.5 Ultrasonic acceptance criteria are shown in Table 5.3.3. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.



(a) Propeller shaft



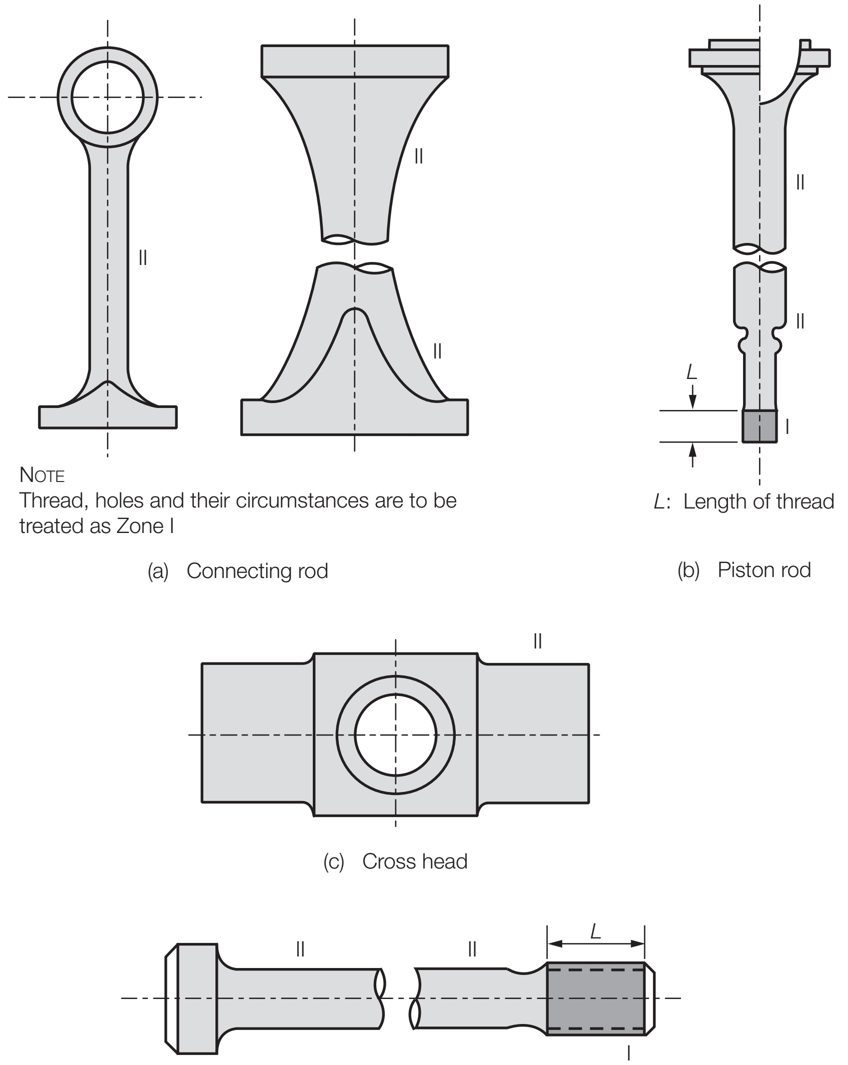
(b) Intermediate shaft



(c) Thrust shaft

NOTE
For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 5.3.4 Zones for magnetic particle/dye penetrant testing on machinery components



NOTE
Thread, holes and their circumstances are to be treated as Zone I

(a) Connecting rod

L: Length of thread

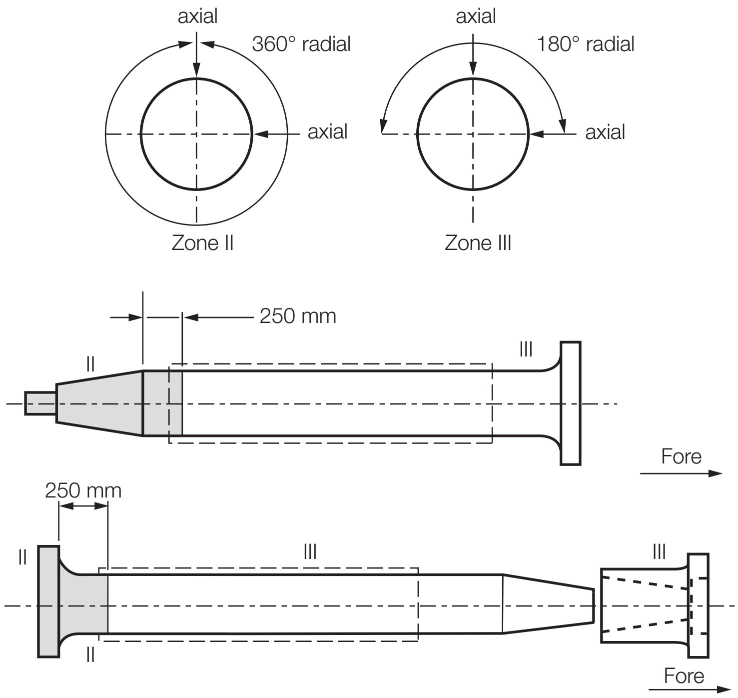
(b) Piston rod

(c) Cross head

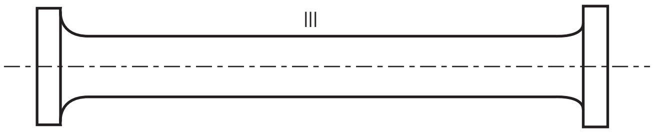
L: Length of thread

(d) Bolt

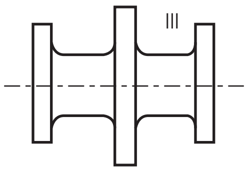
Fig. 5.3.5 Zones for magnetic particle/dye penetrant testing on machinery components



(a) Propeller shaft



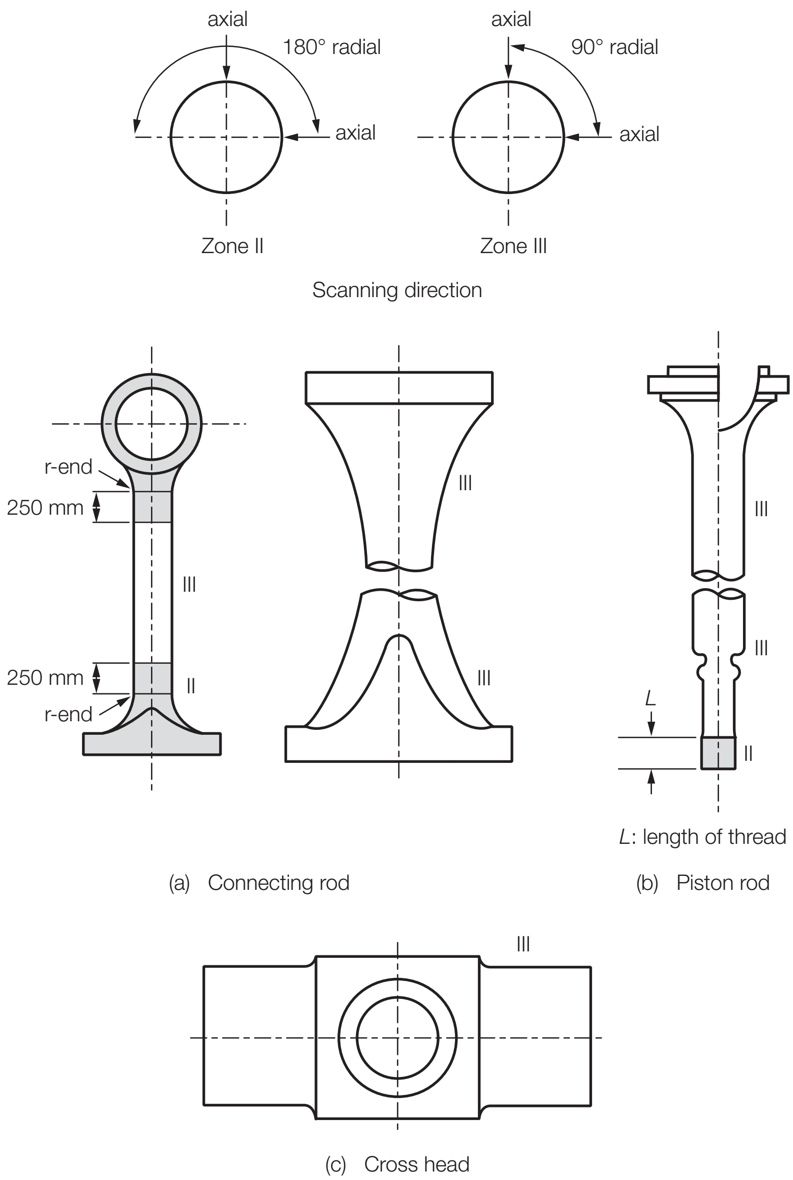
(b) Intermediate shaft



(c) Thrust shaft

NOTES
1. For hollow shafts, 360° radial scanning applies to Zone III
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II
3. Axial scan from end face also required

Fig. 5.3.6 Zones for ultrasonic testing on shafts



NOTE
Axial scan from end face also required

Fig. 5.3.7 Zones for ultrasonic testing on machinery components

Table 5.3.3 Acceptance criteria for ultrasonic testing

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), *see* Note 1, mm	Allowable length of indication, mm *see* Note 2
Propeller shaft Intermediate shaft	II	Outer $d \leq 2$ Inner $d \leq 4$	≤10 ≤15
Thrust shaft Rudder stock	III	Outer $d \leq 3$ Inner $d \leq 6$	≤10 ≤15
Connecting rod Piston rod	II	$d \leq 2$	≤10
	III	$d \leq 4$	≤10

NOTES
1. Outer part means the part beyond one third of the shaft radius from the centre. The inner part means the remaining core area.
2. For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication.

■ *Section 4*
Forgings for crankshafts

4.1 Scope

4.1.1 The specific requirements for solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts are detailed in this Section.

4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition (*see* 1.4.3), heat treatment and mechanical properties are to be submitted for approval. The specified minimum tensile strength is not to exceed 1000 N/mm^2 (1000–1200 N/mm^2 acceptance range).

4.2 Manufacture

4.2.1 For closed die and continuous grain flow crankshafts forgings, where an allowance is given for design purposes, full details of the proposed method of manufacture are to be submitted for approval. In such cases, tests will be required to demonstrate that a satisfactory structure and grain flow are obtained. The number and positions of test specimens are to be agreed with LR.

4.2.2 For the manufacture of welded crankshafts, approval is required for the welding procedure.

4.2.3 For combined crankweb and pin forgings, the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered, but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

4.2.4 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in accordance with 1.2.13, and additionally, unless specially agreed, a depth of at least 7,5 mm is to be removed by machining from all flame-cut surfaces.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

4.3.2 For alloy steel forgings which are to be nitrided, the phosphorus or sulphur contents are not to exceed 0,02 per cent.

4.4 Heat treatment

4.4.1 For forgings in all types of steels, heat treatment is to be either:
(a) normalising and tempering, or
(b) quenching and tempering.
The temperature used for tempering is to be not less than 550°C.

4.4.2 Where it is proposed to surface harden crankshaft forgings by nitriding or induction hardening, full details of the proposed procedure are to be submitted as required by 1.5.6.

4.5 Mechanical tests

4.5.1 At least one tensile test specimen is to be taken from each forging.

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests is to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1).For continuous grain flow (CGF) crankshaft forgings, where insufficient material exists for a second longitudinal test, the second set of tests may be taken in a tangential direction from the crankthrow (test position C in Fig. 5.4.2).

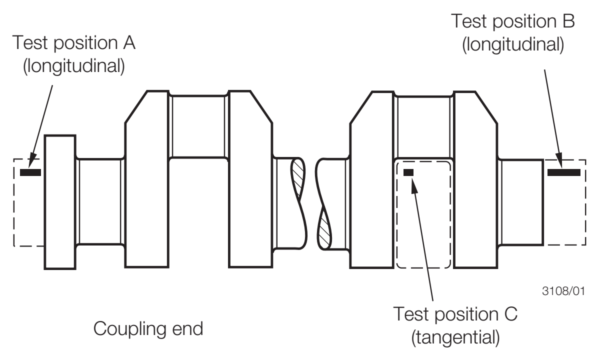


Fig. 5.4.1 Solid forged crankshaft

4.5.3 The number and position of test specimens from combined crankweb and pin forgings are to be in accordance with the requirements of the approved method of manufacture.

4.5.4 For other crankshaft forgings, tests are to be taken as detailed in Section 3, except that for crankwebs the test specimens are to be cut in a tangential direction.

4.5.5 As an alternative to 4.5.2, small solid forged crankshafts may be batch tested in accordance with 1.6.4, provided that, in addition, hardness tests are carried out on each forging.

4.5.6 Tables 5.4.1 to 5.4.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
400–520	200	26	19	110–150
440–560	220	24	18	125–160
480–600	240	22	16	135–175
520–640	260	21	15	150–185
560–680	280	20	14	160–200
600–750	300	18	13	175–215
640–790	320	17	12	185–230
680–830	340	16	12	200–240
720–870	350	15	11	210–250
760–910	380	14	18	225–265
Intermediate values may be obtained by interpolation.				

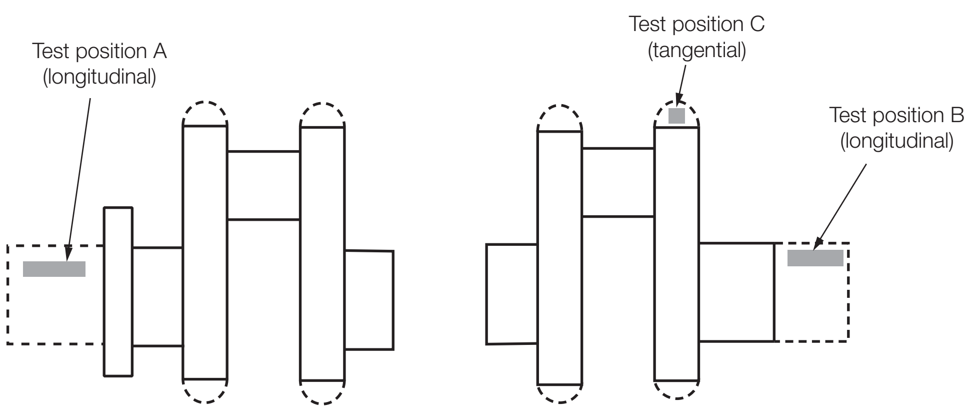


Fig. 5.4.2 CGF Crankshaft

Table 5.4.2 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	330	18	14	175–215
650–800	355	17	13	190–235
700–850	380	16	12	205–245
750–900	405	15	11	215–260
800–950	430	14	10	235–275
Intermediate values may be obtained by interpolation.				

Table 5.4.3 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Quenched and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	420	18	14	175–215
650–800	450	17	13	190–235
700–850	480	16	12	205–245
750–900	530	15	11	215–260
800–950	590	14	10	235–275
850–1000	640	13	9	245–290
900–1100	690	13	9	260–320
950–1150	750	12	8	275–340
1000–1200	810	12	8	290–365
Intermediate values may be obtained by interpolation.				

4.5.7 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.4.1 to 5.4.3.

4.5.8 The results of all tensile tests are to comply with the requirements of Table 5.4.1, 5.4.2 or 5.4.3 appropriate to the specified minimum tensile strength.

4.5.9 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

4.5.10 For small crankshaft forgings which have been batch tested, the hardness values are to be not less than those given in Tables 5.4.1 to 5.4.3, as appropriate. The variation in hardness in each batch is to comply with the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	not more than 25
≥600 <900	not more than 35
≥900	not more than 42

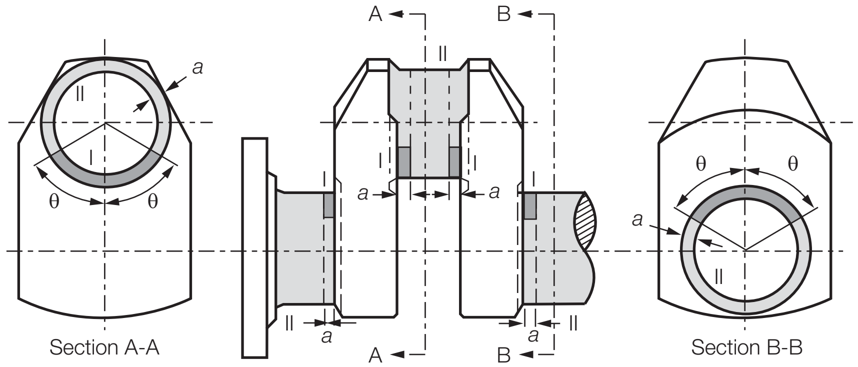
4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 and 2.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in Fig. 5.4.3.

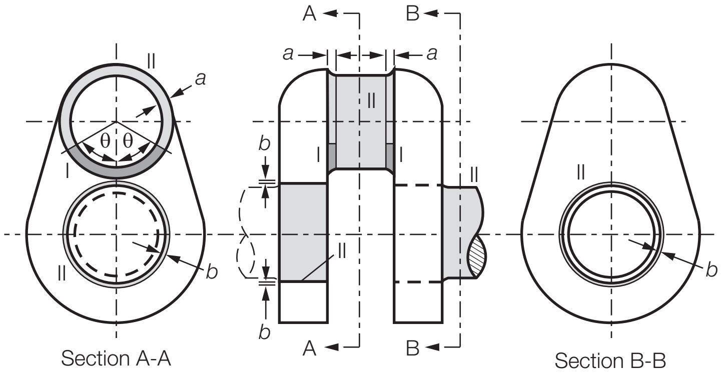
4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in 1.8.8 and 2.5, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks. The extent of ultrasonic testing is shown in Fig. 5.4.4.

4.6.3 Surface inspection acceptance criteria are to be in accordance with 2.5 and with Table 5.4.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

4.6.4 Ultrasonic acceptance criteria are shown in Table 5.4.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.



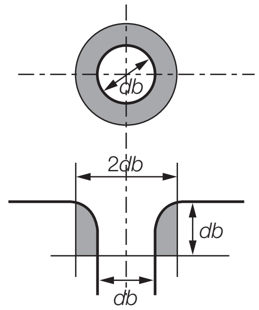
(a) Soild crankshaft



(b) Semi built-up crankshaft

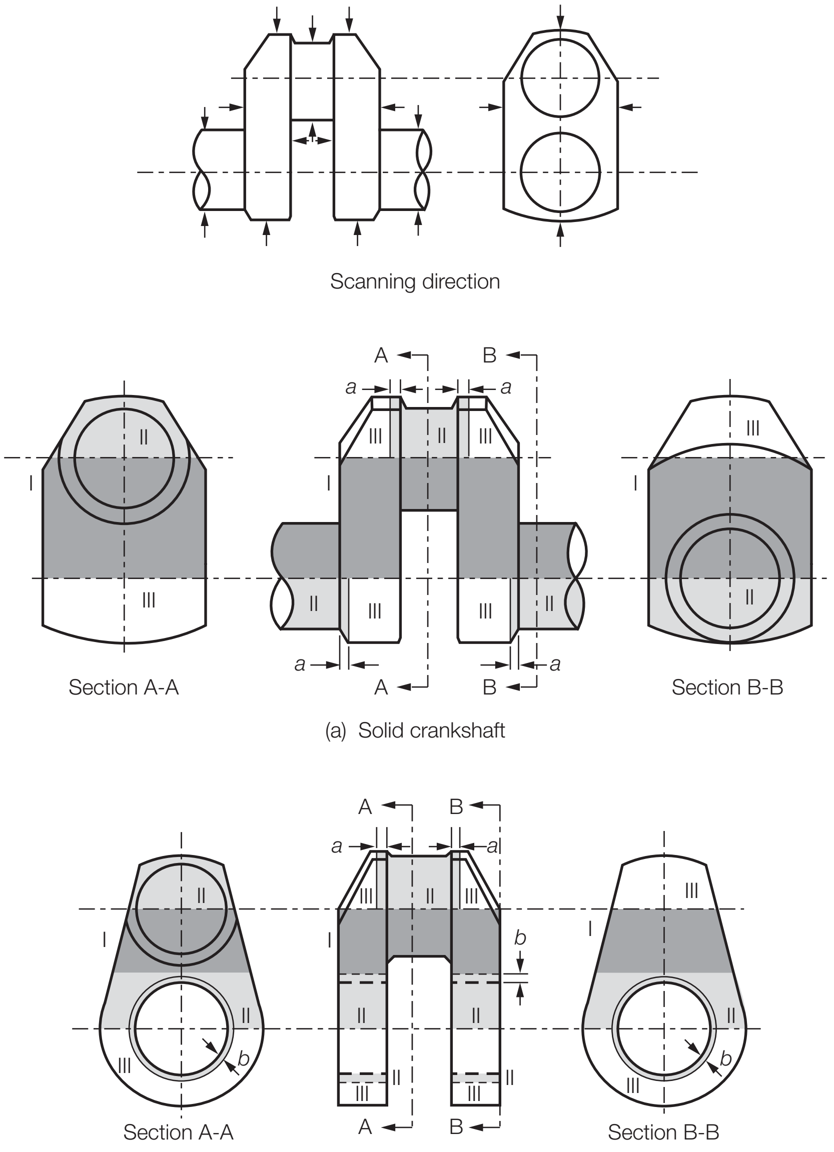
Notes

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil are to be treated as Zone I, (*see* the figure on the right)
2. In the above figures:
   $\theta = 60°$
   $a = 1{,}5r$
   $b = 0{,}05d$ (: circumferential surfaces of shrinkage fit)
   where
   r : fillet radius
   d : journal diameter
3. Identification of the Zones:
   : Zone I
   : Zone II



db: Oil hole bore diameter

Fig. 5.4.3 Zones for magnetic particle/dye penetrant testing on crankshafts



(b) Semi built-up crankshaft

Notes

1. In the above figures:
   a = 0,1*d* or 25 mm, whichever is greater
   b = 0,05*d* or 25 mm, whichever is greater (: circumstances of shrinkage fit)
   where
   d : pin or journal diameter
2. The mid third area of crank pins and/or journals within a raduis of 0,25*d* between the webs may generally be coordinated to Zone II
3. Identification of the Zones:
   : Zone I
   : Zone II
   : Zone III

Fig. 5.4.4 Zones for ultrasonic testing on crankshafts

Table 5.4.4 Surface inspection acceptance for crankshaft forgings – Allowable number and size of indications in a reference area of 225 cm²

Inspection zone	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm
I Critical fillet area	0	Linear Non-linear Aligned	0 0 0	— — —
II Important fillet area	3	Linear Non-linear Aligned	0 3 0	— 3,0 —
III Journal surfaces	3	Linear Non-linear Aligned	0 3 0	— 5,0 —

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), mm	Allowable length of indication, mm *see* Note
Crank shaft	I II III	$d \leq 2{,}0$ $d \leq 3{,}0$ $d \leq 4{,}0$	— ≤10 ≤15

NOTE
For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.

■ *Section 5* Forgings for gearing

5.1 Scope

5.1.1 Provision is made in this Section for carbon-manganese and alloy steel forgings intended for use in the construction of gearing for main propulsion and for driving electric generators.

5.1.2 Gear wheel and rim forgings with a specified minimum tensile strength not exceeding 760 N/mm² (760–910 N/mm² acceptance range) may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm², and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel components and for quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with the requirements of Section 3.

5.1.4 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW (300 shp) for main propulsion and 100 kW (150 shp) for auxiliary drives.

5.2 Manufacture

5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburised material.

5.2.2 The hardenability of the forged material is to be checked at random intervals using an end quench test complying with a National or International Standard.

5.2.3 The grain size is to be checked on a random basis in accordance with the testing and reporting procedures of ASTM E 112, or an equivalent National Standard, and is to be within the range 5 to 8.

5.2.4 The microstructure of the hardened case is to be mainly martensite, with a maximum content of 15 per cent of retained austenite.

5.3 Chemical composition

5.3.1 The chemical composition of ladle samples is to comply with 3.2.1. for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

5.4 Heat treatment

5.4.1 Except as provided in 5.4.4 and 5.4.5, forgings may be either normalised and tempered or quenched and tempered in accordance with the approved specification. The tempering temperature is to be not less than 550°C.

5.4.2 Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburised surface material, taking into account any bending or distortion which may occur.

5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened, i.e, carburised, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

5.4.4 Where induction hardening of nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.4.5 Forgings for gears which are to be carburised after final machining are to be supplied in either the fully annealed or the normalised and tempered condition, suitable for subsequent machining and carburising.

5.5 Mechanical tests for through hardened, induction hardened or nitrided forgings

5.5.1 At least one tensile test specimen is to be taken from each forging in carbon or carbon-manganese steel, and at least one tensile test specimen from forgings in alloy steel. Sufficient test material is to be provided for this purpose and the test specimens are to be taken as follows:

(a) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, tests are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Fig. 5.5.1). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5.1). If, however, the journal diameter is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

(b) For small pinion forgings where the finished diameter of the toothed portion is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1).

(c) For gear wheel forgings, tests are to be taken in a tangential direction (from one of the test positions B in Fig. 5.5.2).

(d) For gear wheel rim forgings, tests are to be taken in a tangential direction (from one of the test positions A in Fig. 5.5.3). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests are to be taken from two diametrically opposite positions (test positions A in Fig. 5.5.3).

(e) For pinion sleeve forgings, tests are to be taken in a tangential direction (from one of the test positions C in Fig. 5.5.4). Where the finished length exceeds 1250 mm, tests are to be taken from each end.

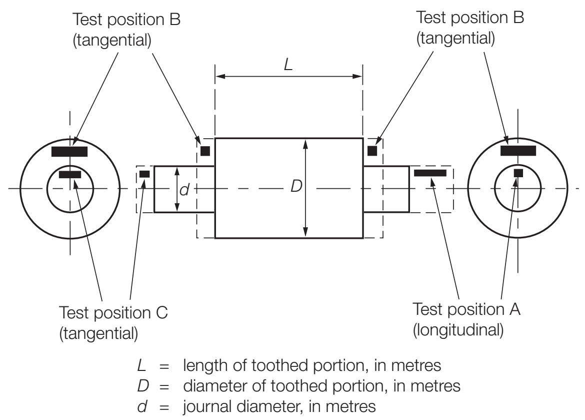


Fig. 5.5.1 Test positions for forgings for gearing

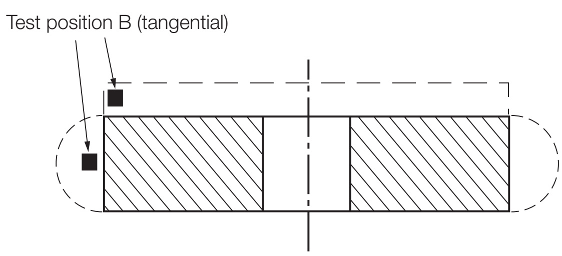


Fig. 5.5.2 Test position B

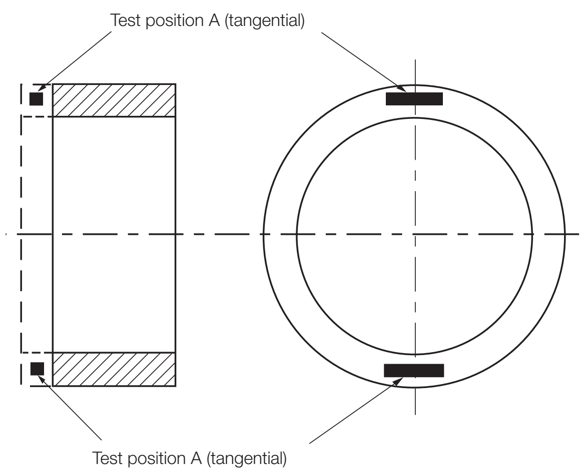


Fig. 5.5.3 Test position A

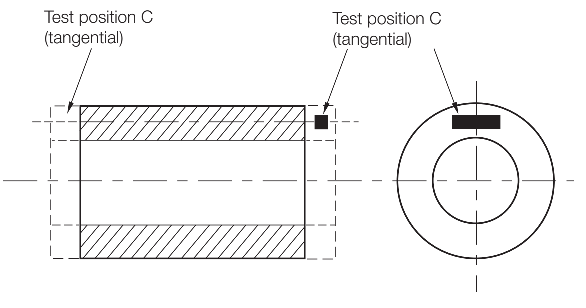


Fig. 5.5.4 Test position C

5.5.2 As an alternative to 5.5.1, small forgings may be batch tested in accordance with 1.6.4 provided that, in addition, hardness tests are carried out on each forging.

5.5.3 Tables 5.5.1 to 5.5.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.5.1 Mechanical properties for acceptance purposes: carbon-manganese steels for gear wheel and rim forgings

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
400–520	200	26	22	110–150
440–560	220	24	21	125–160
480–600	240	22	19	135–175
520–640	260	21	18	150–185
560–680	280	20	17	160–200
600–750	300	18	15	175–215
640–790	320	17	14	185–230
680–830	340	16	14	200–240
720–870	360	15	13	210–250
760– 910	380	14	12	225–265
Intermediate values may be obtained by interpolation.				
NOTE When the specified minimum tensile strength exceeds 700 N/mm^2 forgings are to be supplied only in the quenched and tempered condition.				

5.5.4 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.5.1 to 5.5.3.

5.5.5 The results of all tensile tests are to comply with the requirements of Table 5.5.1, 5.5.2 or 5.5.3, appropriate to the specified minimum tensile strength. Unless otherwise agreed, the specified minimum tensile strength is to be not less than 800 N/mm^2 (800–950 N/mm^2 acceptance range) for induction hardened or nitrided gear forgings.

Table 5.5.2 Mechanical properties for acceptance purposes: alloy steel gear wheel and rim forgings – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
600–750	330	18	16	175–215
650–800	355	17	15	190–235
700–850	380	16	14	205–245
750–900	405	15	13	215–260
800–950	430	14	12	235–275
850–1000	455	13	11	245–290
Intermediate values may be obtained by interpolation.				

Table 5.5.3 Mechanical properties for acceptance purposes: alloy steel gear forgings – Quenched and tempered

Tensile strength N/mm^2 (*see* Notes 1 and 2)	Yield stress N/mm^2 minimum (*see* Note 2)	Elongation on $5{,}65\sqrt{S_o}$ % minimum			Hardness Brinell
		A	B	C	
600–750	420	18	16	14	175–215
650–800	450	17	15	13	190–235
700–850	480	16	14	12	205–245
750–900	530	15	13	11	215–260
800–950	590	14	12	10	235–275
850–1000	640	13	11	9	245–290
900–1050	690	13	11	9	260–310
950–1100	750	12	10	8	275–330
1000–1150	810	12	10	8	290–340
1050–1200	870	11	9	7	310–365
Column A is applicable to tests from gear rims and to longitudinal tests from pinions. Column B is applicable to tests from gear wheels and to tangential tests from pinions. Column C is applicable to tests from pinion sleeves.					
Intermediate values may be obtained by interpolation.					
NOTES 1. For gear wheel and rim forgings the specified minimum tensile strength is not to exceed 850 N/mm^2. 2. For carburised gear forgings the requirements for minimum yield stress and maximum tensile strength are not applicable.					

5.5.6 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

5.5.7 Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2500 mm, the number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging.

5.5.8 For small gear forgings which are batch tested, at least one hardness test is to be carried out on each forging.

5.5.9 The results of all hardness tests are to comply with the appropriate requirements of Tables 5.5.1 to 5.5.3. The difference between the highest and lowest values on any one forging is not to exceed the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	25
≥600 <900	35
≥900	42

5.5.10 On nitrided or induction hardened components, hardness tests are also to be made on the teeth when surface hardening and grinding have been completed. The results are to comply with the approved specification.

5.6 Mechanical tests for carburised forgings

5.6.1 Sufficient test material is to be provided for preliminary tests at the forge and for final tests after completion of carburising. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 5.5.1, except that, irrespective of the dimensions or mass of the forging, tests are required from one position only, and in the case of forgings with integral journals are to be cut in a longitudinal direction. The test material which is to be used for measurements of case depth, hardness, grain size and residual austenite as well as mechanical properties is to be machined to a coupon of diameter of $\frac{D}{4}$ or 30 mm, whichever is less, where D is the finished diameter of the toothed portion.

5.6.2 For small forgings, where a system of batch testing is adopted, the test material may be prepared from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings. The test samples are to be correctly identified and heat treated with the forgings they represent.

5.6.3 For preliminary tests at the forge, one set of test material is to be given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings.

5.6.4 For final acceptance tests, the second set of test material is to be blank carburised and heat treated together with the forgings which it represents.

5.6.5 At the discretion of the forgemaster or gear manufacturer, test samples of larger cross-section than in 5.6.1 may be either carburised or blank carburised, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

5.6.6 At least one tensile specimen is to be prepared from each sample of test material.

5.6.7 Unless otherwise agreed, the specified minimum tensile strength is to be not less than 750 N/mm^2, and the results of all tensile tests are to comply with the requirements given in Table 5.5.3.

5.6.8 Where it is proposed to adopt alternatives to the requirements of 5.6.1 to 5.6.7, full details are to be submitted to the Surveyor for consideration.

5.7 Non-destructive examination

5.7.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.7.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

5.7.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, (i.e., depth to core hardness), is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 HV.

■ *Section 6* Forgings for turbines

6.1 Scope

6.1.1 Provision is made in this Section for ferritic steel forgings for turbine rotors, discs and spindles, turbine-driven generator rotors and compressor rotors.

6.1.2 Plans for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability, the maximum operating temperature and the proposed test temperature are also to be stated.

6.1.3 Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

6.1.4 Where it is proposed to use rotors of welded construction, the compositions of the steels for the forgings are to be submitted for special consideration, together with details of the proposed welding procedure. Welding procedure tests may be required.

6.2 Manufacture

6.2.1 Forgings are to be manufactured in accordance with the requirements of Section 1, except that for rotors the forging reduction is to be not less than 2,5 to 1. Where an upsetting operation is included in the manufacturing procedure, the above requirement applies to the cross-sectional area of the upset bloom and not to that of the ingot.

6.3 Chemical composition

6.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

6.4 Heat treatment

6.4.1 Forgings are to be supplied in the heat treated condition, and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

6.4.2 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings which are heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

6.4.3 The tempering and stress relieving temperatures are to be not less than 550°C for carbon and carbon-manganese steels, and not less than 600°C for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

6.4.4 Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

6.5 Mechanical tests

6.5.1 At least one tensile test specimen, cut in a longitudinal direction, is to be taken from each rotor forging. For forgings exceeding both 3 tonnes in mass and 2000 mm in length, tests are to be taken from each end.

6.5.2 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW, tangential and, where the dimensions permit, radial tensile tests are to be taken from the end of the body corresponding to the top end of the ingot, *see* Fig. 5.6.1.

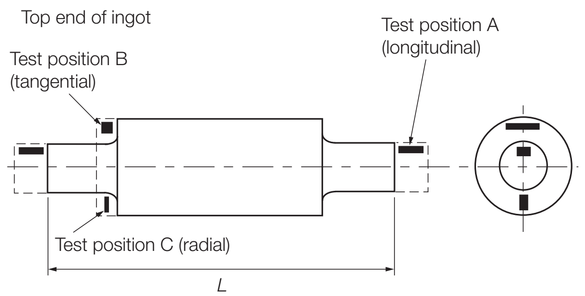


Fig. 5.6.1 Test positions for turbine rotor forgings

6.5.3 For each turbine disc, at least one tensile test specimen is to be cut in a tangential direction from material at the hub, *see* Fig. 5.6.2.

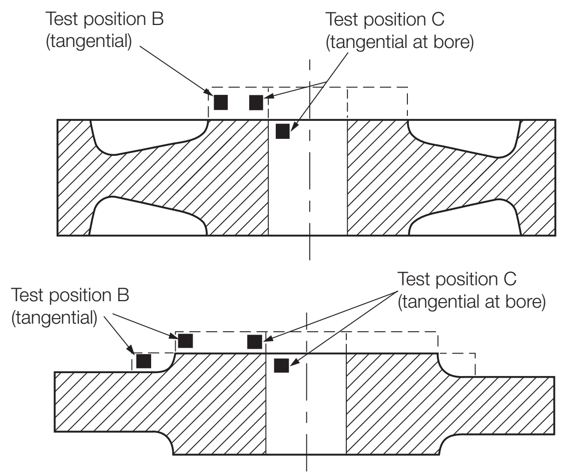


Fig. 5.6.2 Test positions for turbine disc forgings

6.5.4 For the tests required by 6.5.1 to 6.5.3, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed. In this connection, a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

6.5.5 Tables 5.6.1 and 5.6.2 give the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 for alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.6.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for turbines – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation $5{,}65\sqrt{S_o}$ % minimum			Reduction of area % minimum		
		A	B	C	A	B	C
400–520	200	26	22	18	50	40	35
440–560	220	24	21	17	50	40	35
480–600	240	22	19	15	45	35	30
520–640	260	21	18	14	45	35	30
560–680	280	20	17	13	40	30	25
600–720	300	18	15	12	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor forgings.
Columns C are applicable to radial tests from rotor forgings.
Intermediate values may be obtained by interpolation.

6.5.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.6.1 or Table 5.6.2.

6.5.7 The results of all tensile tests are to comply with the requirements of Table 5.6.1 or Table 5.6.2 appropriate to the specified minimum tensile strength. For monobloc rotor forgings, the specified minimum tensile strength is not to exceed 800 N/mm^2.

6.6 Non-destructive examination

6.6.1 The end faces of the body of rotor forgings and the end faces of the boss and the bore surface of each turbine disc are to be machined to a fine smooth finish for visual and magnetic particle examination.

6.6.2 The manufacturer is to carry out an ultrasonic examination of each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

6.6.3 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Table 5.6.2 Mechanical properties for acceptance purposes: alloy steel forgings for turbines – Quenched and tempered or normalised and tempered

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum Normalised and tempered	Yield stress N/mm^2 minimum Quenched and tempered	Elongation on $5{,}65\sqrt{S_o}$ % minimum			Reduction of area %minimum		
			A	B	C	A	B	C
500 – 650	275	—	22	20	18	50	40	35
550 – 700	300	—	20	18	16	50	40	35
600 – 750	330	410	18	16	14	50	40	35
650 – 800	355	450	17	15	13	50	40	35
700 – 850	385	490	16	14	12	45	35	30
750 – 900	—	530	15	13	11	45	35	30
800 – 950	—	590	14	12	10	45	35	30
850 – 1000	—	640	13	11	9	40	30	25
900 – 1050	—	690	13	11	9	40	30	25
950 – 1100	—	750	12	10	8	40	30	25
1000 – 1150	—	810	12	10	8	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor and spindle forgings, and to tangential tests from discs – test position B in Fig. 5.6.2.
Columns C are applicable to radial test from rotor forgings and to tangential tests from discs – test position C in Fig. 5.6.2.
Intermediate values may be obtained by interpolation.

6.7 Thermal stability tests

6.7.1 Thermal stability tests after heat treatment and rough machining of the turbine rotors, referred to in the relevant Rules dealing with design and construction, are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:

(a) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.

(b) Four positions, 90° apart, are to be stamped A, B, C and D on the coupling end of the rotor.

(c) The whole of the body, and as much of the shaft at either end as will include the positions of the glands, is to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test.

(d) The rotor is to be rotated at a uniform and very low speed.

(e) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.

(f) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and, if practicable, in the bore at the mid-length of the body. In no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating, the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.

(g) The maximum or holding temperature is to be not less than 28°C above the maximum operating temperature of the rotor. For the purposes of the test, the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.

(h) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.

(j) Final cold readings are to be taken.

6.7.2 The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings. The radial movement of the shaft axis, as determined by the difference between the final hot and the final cold movements, is not to exceed 0,025 mm on any one band. As verification that test equipment and conditions are satisfactory, it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

6.7.3 If the results of the test on a rotor fail to meet either or both of the requirements in 6.7.2, the test may be repeated if requested by the maker and agreed by the Surveyor. In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

■ *Section 7*
Forgings for boilers, pressure vessels and piping systems

7.1 Scope

7.1.1 Provision is made in this Section for carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C.

7.1.2 In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

7.1.3 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8, except for those used in piping systems, where the design temperature is not lower than 0°C. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the appropriate requirements of Table 5.7.1.

7.3 Heat treatment

7.3.1 Carbon-manganese steel forgings are to be normalised, normalised and tempered or quenched and tempered.

7.3.2 Alloy steel forgings are to be normalised and tempered or quenched and tempered.

7.3.3 No forging is to be fully heat treated more than twice.

7.4 Mechanical tests

7.4.1 Except as provided in 7.4.2 and 7.4.4, at least one tensile test is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.

Table 5.7.1 Chemical composition

Type of steel	Tensile strength N/mm^2	Chemical composition of ladle samples %							
		C max.	Si	Mn	P max.	S max.	Al	Residual elements	
Carbon-manganese	410–530	0,20	0,10–0,40	0,50–1,20	0,030	0,025	(*See* Notes 1 and 3)	Ni 0,40 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,80 max.	
	460–580	0,23		0,80–1,40					
	490–610	0,25		0,90–1,70					
Alloy steel								Cr	Mo
1Cr^1/2Mo	440–590	0,18	0,15–0,40	0,40–0,70	0,030	0,025	0,020 max. (*See* Note 2)	0,85–1,15	0,45–0,65
2^1/4 Cr1Mo	490–640	0,15						2,0–2,5	0,90–1,20

NOTES
1. Fine grained steels are to contain:
   aluminium (acid soluble) 0,015% min. or
   aluminium (total) 0,018% min.
2. For alloy steels, aluminium (acid soluble) 0,020% max.
   The determination of the aluminium (total) content is acceptable provided the above value is not exceeded.
3. Niobium may be used as a grain refiner in place of aluminium, in which case the content is to be in the range 0,01% to 0,06%.

7.4.2 On seamless drums and headers which are initially forged with open ends, test material is to be provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases, the test specimens are to be cut in the circumferential direction.

7.4.3 Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12,5 mm below the surface of the forging.

7.4.4 Small forgings may be batch tested in accordance with 1.6.4 provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 tonne and that of the batch is not to exceed 10 tonnes and the hardness values are to accord with Table 5.7.2.

Table 5.7.2 Mechanical properties for acceptance purposes

Type of steel	Diameter or equivalent thickness mm	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Hardness Brinell
Carbon-manganese not specifically fine grained	≤100	215	410–530	20	110–155
	>100 ≤500	205			
	≤100	245	460–580	18	130–170
	>100	235			
	≤100	265	490–610	16	140–180
	>100	255			
Carbon-manganese, fine grained	≤100	235	410–530	20	110–155
	>100 ≤250	220			
	≤100	275	460–580	18	130–170
	>100 ≤250	255			
	≤100	305	490–610	16	140–180
	>100 ≤250	280			
Alloy steel 1Cr^1/2Mo	–	275	440–590	19	110–160
2^1/4Cr1Mo	–	275	490–640	18	140–185

7.4.5 If required by the Surveyors or by the Fabricators, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order, together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

7.4.6 Except as provided in 7.4.7, the results of all tensile tests are to comply with the requirements given in Table 5.7.2 appropriate to the specified minimum tensile strength.

7.4.7 Where tests are taken at a depth greater than 12,5 mm from the surface or where they are taken in a transverse direction, the mechanical properties which can be expected are to be agreed.

7.4.8 On seamless drums and headers where tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

7.4.9 For small batch-tested forgings, the hardness values are to comply with the requirements of Table 5.7.2 appropriate to the specified minimum tensile strength. If forgings of more than one thickness are to be supplied from one cast, then the test is to be made on the thickest forging.

7.5 Non-destructive examination

7.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

7.6 Pressure tests

7.6.1 Where applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

7.7 Mechanical properties for design purposes

7.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 5.7.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.7.3.

Table 5.7.3 Mechanical properties for design purposes

Type of steel	Diameter or equivalent thickness mm	Tensile strength N/mm^2	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
			Temperature °C											
			50	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese not specifically fine grained	≤100	410–530	196	192	188	181	168	150	142	138	136	—	–	—
	>100		183	178	175	170	162	150	142	138	136	—	—	—
	≤100	460–580	227	222	218	210	194	176	168	162	158	—	—	—
	>100		212	206	203	197	188	176	168	162	158	—	—	—
	≤100	490–610	245	240	236	227	210	192	183	177	172	—	—	—
	>100		229	222	219	212	203	192	183	177	172	—	—	—
Carbon-manganese fine grained	≤100	410–530	222	215	204	188	171	152	141	134	130	—	—	—
	>100		207	200	190	175	164	152	141	134	130	—	—	—
	≤100	460–580	262	251	236	217	198	177	167	158	153	—	—	—
	>100		244	233	220	202	190	177	167	158	153	—	—	—
	≤100	490–610	286	272	256	234	213	192	182	173	168	—	—	—
	>100		266	253	238	218	205	192	182	173	168	—	—	—
Alloy steel 1Cr$^1/_2$Mo	—	410–560	254	241	224	213	197	184	170	162	157	151	146	145
2$^1/_4$ Cr1Mo	—	490–640	268	261	253	245	236	230	224	218	205	189	167	145

7.7.2 Where verification is required, at least one tensile test at the proposed design or other agreed temperature is to be made on each forging or each batch of forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

7.7.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 5.7.4 and may be used for design purposes.

Table 5.7.4 Mechanical properties for design purposes: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Grades of steel		
	Carbon-manganese	1 Cr 1/2 Mo	2 1/4 Cr 1Mo
380	227	–	–
390	203	–	–
400	179	–	–
410	157	–	–
420	136	–	–
430	117	–	–
440	100	–	–
450	85	290	–
460	73	262	–
470	63	235	210
480	55	208	186
490	–	181	165
500	–	155	145
510	–	129	128
520	–	103	112
530	–	80	98
540	–	62	84
550	–	49	72
560	–	42	61
570	–	36	49
580	–	32	–
590	–	29	–

■ *Section 8* Ferritic steel forgings for low temperature service

8.1 Scope

8.1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this Section. They are applicable to all forgings used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and, where the design temperature is less than 0°C, to forgings for the piping systems.

8.1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.1.4 In addition to the steels in this Section, the austenitic stainless steels detailed in Section 9 may also be used for low temperature applications.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 5.8.1.

8.3 Heat treatment

8.3.1 Forgings are to be normalised, normalised and tempered or quenched and tempered in accordance with the approved specification.

8.4 Mechanical tests

8.4.1 At least one tensile and three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

8.4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.6.3 in Chapter 3.

8.4.3 The results of all tensile tests are to comply with the approved specification.

8.4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch 3,6. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4 for re-test procedures.

Table 5.8.1 Chemical composition of ferritic steel forgings

Grade of steel	C %	Si %	Mn %	Ni %	P %	S %	Residual elements %	Grain refiners % Al	Grain refiners % Other
LT–AH (AH40) LT–DH (DH40) LT–EH (EH40)	0,18 max.	0,50 max.	0,90–1,60	0,40 max.	0,035 max.	0,030 max.	Cu 0,35 max. Cr 0,20 max. Mo 0,08 max. Total 0,60 max.	Total 0,020 min. Acid soluble 0,015 min.	(*See* Note) Nb 0,02 – 0,05 V 0,03 – 0,10 Ti 0,02 max.
LT–FH (FH40)	0,16 max.			0,80 max.	0,025 max.	0,025 max.			
1½Ni	0,18 max.	0,10 – 0,35	0,30–1,50	1,30–1,70		0,020 max.	Cu 0,35 max. Cr 0,25 max. Mo 0,08 max. Total 0,60 max.		
3½Ni	0,15 max.		0,30–0,90	3,20–3,80					
5Ni	0,12 max.			4,70–5,30					
9 Ni	0,10 max.			8,50–10,0					

NOTE
The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.

8.5 Non-destructive examination

8.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

8.6 Pressure tests

8.6.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

■ *Section 9* Stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic and duplex stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

9.1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval. These are to comply, in general, with the requirements of Ch 3,7 for austenitic steel plates.

9.2 Chemical composition

9.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 5.9.1.

9.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 5.9.1.

9.3 Heat treatment

9.3.1 All materials are to be supplied in the solution treated condition.

9.4 Mechanical tests

9.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 1.7.

9.4.2 The results of all tensile tests and impact tests are to comply with the requirements of Table 5.9.2 or the approved specification.

9.4.3 For austenitic stainless steel forgings, impact tests may be omitted subject to prior agreement with LR.

Table 5.9.1 Chemical composition of stainless steel forgings

Type of steel	Chemical composition % (*see* Note)								
	C	Si	Mn	S	P	Cr	Mo	Ni	Others
Austenitic									
304L	0,03	1,00	2,00	0,030	0,045	18,0–20,0	–	8,0–13,0	—
304	0,08					18,0–20,0	–	8,0–11,0	—
316L	0,03					16,0–18,0	2,0–3,0	10,0–15,0	—
316	0,08					16,0–18,0	2,0–3,0	10,0–14,0	—
317	0,08					18,0–20,0	3,0–4,0	11,0–15,0	—
347	0,08					17,0–20,0	–	9,0–13,0	Nb ≥ 10 x C ≤ 1,10
Duplex									
UNS S 31803	0,03	1,00	2,00	0,020	0,030	21,0–23,0	2,5–3,5	4,5–6,5	N 0,08–0,20
UNS S 32750	0,03	0,80	1,20	0,020	0,035	24,0–26,0	3,0–5,0	6,0–8,0	N 0,24–0,32 Cu 0,50

NOTE
Where a single value is shown (and not a range of values), the value is to be taken as maximum.

Table 5.9.2 Mechanical properties for acceptance purposes: stainless steel forgings

Type of steel	Tensile strength N/mm^2 minimum	1,0% proof stress N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
Austenitic						
304L	485	170	30	50	–196	41
304	515	205				
316L	485	170				
316	515	205				
317	515	205				
347	515	205				
Duplex						
UNS S 31803	620	450	25	45	–20	41
UNS S 32750	800	550	15	40		

9.5 Mechanical properties for design purposes

9.5.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 5.9.3 may be used for design purposes. Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 5.9.3.

9.6 Non-destructive examination

9.6.1 Non-destructive examination is to be carried out in accordance with the requirements of the approved forging drawing and specification or as otherwise agreed between the manufacturer, purchaser and Surveyor.

9.7 Corrosion tests

9.7.1 Where corrosive conditions are anticipated in service, for grades 304, 316 and 317 intergranular corrosion tests are required in accordance with Ch 2,8.1. Such tests may also be required for grades 304L, 316L and 347.

9.7.2 Where corrosive conditions are anticipated in service, for duplex stainless grades pitting corrosion tests are required in accordance with ASTM G48 Method C. For UNS S 31803 duplex stainless steels the test temperature is to be 25°C. Following the test, no pitting corrosion is to be observed at 20x magnification. The use of a weight loss method may be accepted subject to special consideration.

Table 5.9.3 Mechanical properties for design purposes: austenitic stainless steels

Grade	Nominal 1% proof stress (N/mm^2) at a temperature of												
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	—	—

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2, 3, 4, 5 and 6.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of Section 4 or 5.

1.1.5 As an alternative to 1.1.3 and 1.1.4, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for oil fuel systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 4,0 bar (4,1 kgf/cm^2).

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in Ch 3,1.4.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:

- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.
- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated together in the same batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in Table 6.1.1. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 140 bar (143 kgf/cm^2):

$$P = \frac{20st}{D} \left(P = \frac{200st}{D}\right)$$

where

P = test pressure, in bar (kgf/cm^2)
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 80 per cent of the specified minimum yield stress, in N/mm^2 (kgf/mm^2), for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2 (kgf/mm^2), for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in 1.10.2, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) The personal stamp of the Surveyor responsible for the final inspection.

1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification of materials

1.13.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.13.2 The manufacturer is to provide LR with the following information:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.
(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.
(j) Condition of supply.

1.13.3 As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2*
Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in Ch 5,7 are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.2.1.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %											
			C	Si	Mn	S max.	P max.	Residual elements						
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	–	0,40–0,70	0,050	0,050	Ni 0,30 max.						
	360		≤0,17	≤0,35	0,40–0,80	0,045	0,045	Cr 0,25 max.						
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045	Mo 0,10 max.						
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045	Cu 0,30 max.						
	490		≤0,23	≤0,35	0,80–1,50	0,045	0,045	Total 0,70 max.						
								Ni	Cr	Mo	Cu	Sn	V	Al
1Cr$^1/_2$Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45 – 0,65	0,25 max.	0,03 max.	—	≤0,020
2$^1/_4$Cr1Mo	410 490	Killed	0,08–0,15	0,10–0,50	0,40–0,70	0,040	0,040	0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	—	≤0,020
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30	0,30–0,60	0,50–0,70	0,25 max.	0,03 max.	0,22–0,32	≤0,020

2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in Table 6.2.3.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in Section 1.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.2.2.

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 6.2.4 and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in Table 6.2.4.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in Chapter 2. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.3 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalised (*see* Note 2)
Cold finished		Normalised (*see* Note 2)
Alloy steel		
1Cr$^1/_2$Mo		Normalised and tempered
2$^1/_4$Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalised and tempered 650—780°C
	Grade 490	Normalised and tempered 650—750°C
$^1/_2$Cr$^1/_2$Mo$^1/_4$V		Normalised and tempered

NOTES
1. Provided that the finishing temperature is sufficiently high to soften the material.
2. Normalised and tempered at the option of the manufacturer.

2.5.3 As an alternative to 2.5.2, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in Table 6.2.5 and may be used for design purposes.

Table 6.2.2 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_0}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	4t
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
1Cr$^1/_2$Mo	440	275	440—590	22	0,07	4t
2$^1/_4$Cr1Mo	410 (*see* Note 1)	135	410—560	20	0,07	
	490 (*see* Note 2)	275	490—640	16		4t
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	275	460—610	15	0,07	4t

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr$^1/_2$Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2$^1/_2$Cr1Mo	410 (*see* Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (*see* Note 2)	268	261	253	245	236	230	224	218	205	189	167	145
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	266	259	248	235	218	192	184	177	168	155	148	—

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes – Estimated values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Carbon and carbon-manganese		1Cr$^1/_2$Mo	2$^1/_4$Cr1Mo		$^1/_2$Cr$^1/_2$Mo$^1/_4$V
	Grade 320 360 410	Grade 460 490	Grade 440	Grade 410 Annealed	Grade 490 Normalised and tempered (*see* Note)	Grade 460
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

NOTE
When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

■ *Section 3*
Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.3.1.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in Table 6.3.3.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in Section 1.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.3.2.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and 1Cr½Mo steel can be taken from the appropriate Tables in Section 2.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %										
			C	Si	Mn	S max.	P max.	Residual elements					
Carbon and carbon-manganese	320	Any method (see Note)	≤0,16	–	0,30–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.					
	360	Killed	≤0,17	≤0,35	0,40–1,00	0,045	0,045						
	410		≤0,21	≤0,35	0,40–1,20	0,045	0,045						
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045						
								Ni	Cr	Mo	Cu	Sn	Al
1Cr½Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45–0,65	0,25 max.	0,03 max.	≤0,020

NOTE
For rimming steels, the carbon content may be increased to 0,19% max.

Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320 – 440 360 – 480 410 – 530 460 – 580	25 24 22 21	0,10 0,10 0,08 0,07
1Cr$^1/_2$Mo	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalised (Normalised and tempered at the option of the manufacturer)
1Cr$^1/_2$Mo	Normalised and tempered

NOTE
Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications:
(a) Class 2 piping systems, except for liquefied gases or other low temperature applications.
(b) Class 3 piping systems.

■ *Section 4* Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms ‘hot finished’, ‘cold finished’ and ‘as-welded’ apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.4.1.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in Table 6.4.3.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in Section 1 for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in Table 6.4.2.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of Chapter 2.

4.4.5 The results of all tensile, flattening and bend tests are to comply with the appropriate values in Table 6.4.2.

4.4.6 The average value for impact test specimens is to comply with the appropriate requirements of Table 6.4.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4.1 for re-test procedures.

Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %							
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements
Carbon	360	Fully killed	0,17	0,10—0,35	0,40—1,00	0,030	0,025	—	0,015 min.	Cr 0,25 Cu 0,30 Mo 0,10 Ni 0,30 Total 0,70
Carbon-manganese	410 and 460		0,20	0,10—0,35	0,60—1,40	0,030	0,025	—	0,015 min.	
$3^{1}/_{2}$Ni	440		0,15	0,15—0,35	0,30—0,90	0,025	0,020	3,25—3,75	—	Cr 0,25 Cu 0,30 Mo 0,10 Total 0,60
9Ni	690		0,13	0,15—0,30	0,30—0,90	0,025	0,020	8,50—9,50	—	

NOTE
Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360—480	24	0,10	4t	–40	27
Carbon-manganese	410 460	235 260	410—530 460—580	22 21	0,08 0,07	4t	–50	27
$3^{1}/_{2}$Ni	440	245	440—590	16	0,08	4t	–95	34
9Ni	690	510	690—840	15	0,08	4t	–196	41

For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J 34 J 41 J	22 J 28 J 34 J	18 J 23 J 27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished Normalised Normalised and tempered
$3^{1}/_{2}$ Ni	Normalised Normalised and tempered
9Ni	Double normalised and tempered Quenched and tempered

■ *Section 5* Austenitic stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels are also suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see* Ch 1,2.2.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 6.5.1.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in Section 1 for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.5.2.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition of ladle sample %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
304L	490	0,03	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	—
316L	490	0,03	<1,00	<2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	11,0 – 14,5	—
321	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Ti ≥5 x C ≤0,80
347	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Nb ≥10 x C ≤1,00

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (*see* Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*

NOTE
The 0,2% proof stress values given for information purposes and unless otherwise agreed are not required to be verified by test.

5.5 Intergranular corrosion tests

5.5.1 For materials used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with Ch 2,9.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of Chapter 2. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with 5.2, 5.3, 5.4 and 5.5.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion.

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in Ch 1,3.1 together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in Table 6.5.1.

■ *Section 6* Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of Sections 2 and 3, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 6.2.1 or 6.3.1, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in Table 6.2.3 or 6.3.3 as appropriate, except that 1Cr$^1/_2$Mo steel may be supplied in the normalised only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in Section 1.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:
(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.6.1.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr$^1/_2$Mo and 2$^1/_4$Cr1Mo steels can be taken from the appropriate Tables in Section 2.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

Table 6.6.1 **Mechanical properties for acceptance purposes: boiler and superheater tubes**

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter Ratio $\frac{\text{Inside diameter}}{\text{Outside diameter}}$ ≤0,6	>0,6 ≤0,8	>0,8
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320–440 360–480 410–530 460–580	25 24 22 21	0,10 0,10 0,08 0,07	4*t*	12 12 10 8	15 15 12 10	19 19 17 15
1Cr$^1/_2$Mo	440	275	440–590	22	0,07	4*t*	8	10	15
2$^1/_2$Cr1Mo	410 (*see* Note 1) 490 (*see* Note 2)	135 275	410–560 490–640	20 16	0,07	4*t*	8	10	15

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for grey (flake), spheroidal (nodular) graphite and compacted (vermicular) graphite iron castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the requirements given in this Section and either Section 2 for grey iron castings, Section 3 for spheroidal graphite iron castings or Section 4 for compacted graphite iron castings. Castings for crankshafts are additionally to comply with the requirements detailed in Section 5.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.2, may be adopted subject to approval by Lloyd's Register (hereinafter referred to as 'LR').

1.2 Manufacture

1.2.1 Castings as designated in 1.1.2 are to be made at foundries approved by LR.

1.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

1.3 Quality of castings

1.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

1.4 Chemical composition

1.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

1.5 Heat treatment

1.5.1 Except as required by 1.5.2, castings may be supplied in either the as cast or heat treated condition.

1.5.2 For some applications, such as elevated temperature service, or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining.

1.5.3 Where it is proposed to carry out local hardening of the surface of a casting, full details of the proposed procedure are to be submitted for approval.

1.6 Test material

1.6.1 At least one test sample is to be provided for each casting or batch of castings. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

1.6.2 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of metal. One test sample is to be provided for each multiple of two tonnes of fettled castings in the batch.

1.6.3 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the temperature is below 500°C.

1.6.4 All test samples are to be suitably marked to identify them with the castings which they represent.

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on test samples, the sample is not to be separated from the casting until after heat treatment.

1.7 Mechanical tests

1.7.1 One tensile specimen is to be prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Section 2, 3, 4 or 5, as appropriate.

1.7.3 In the case of castings supplied in the as cast condition which initially do not meet the requirements of 1.7.2, the manufacturer, by agreement with the purchaser, has the right to heat treat the castings, together with the representative test samples, and re-submit them for acceptance.

1.7.4 In the case of a batch of castings supplied in the heat treated condition which initially do not meet the requirements of 1.7.2, the manufacturer has the right to re-heat treat the batch together with the representative test samples, and re-submit the castings for acceptance. The number of reheat treatments and retestings will be restricted to two.

1.8 Visual and non-destructive examination

1.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.8.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

1.8.3 All castings are to be presented to the Surveyor for visual examination and this is to include the examination of internal surfaces where applicable.

1.8.4 The non-destructive examination of castings is not required unless otherwise stated in the approved plan or where there is reason to suspect the soundness of the casting.

1.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.9 Rectification of defective castings

1.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

1.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by vacuum impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

1.9.3 Repairs by welding are not permitted on grey cast iron castings or compacted graphite iron castings and generally not permitted for spheroidal or nodular graphite iron castings, but may be considered in special circumstances for spheroidal or nodular graphite iron castings. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.10 Pressure testing

1.10.1 When required by the relevant Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence and to the satisfaction of the Surveyor.

1.11 Identification of castings

1.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the castings when required.

1.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:
(a) Type and grade of cast iron.
(b) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(c) Manufacturer's name or trade mark.
(d) LR or Lloyd's Register and the abbreviated name of LR's local office.
(e) Personal stamp of Surveyor responsible for inspection.
(f) Test pressure, where applicable.
(g) Date of final inspection.

1.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and quality of cast iron.
(c) Identification number.
(d) General details of heat treatment, where applicable.
(e) Results of mechanical tests.
(f) Test pressure, where applicable.
(g) When specially required, the chemical analysis of ladle samples.

1.12.3 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.8, together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.

■ *Section 2* Grey iron castings

2.1 Scope

2.1.1 This Section gives the specific requirements for grey cast iron castings.

2.2 Test material

2.2.1 Separately cast test samples in the form of cylindrical bars, 30 mm diameter and of a suitable length, are to be used unless otherwise agreed by LR. Test samples of other dimensions may be specially required for some components as may cast-on samples. In these circumstances, the tensile strength requirements are to be agreed.

2.2.2 When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

2.2.3 Test samples may be cast integrally when a casting is both more than 20 mm thick and its mass exceeds 200 kg, subject to agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and are also subject to agreement.

2.2.4 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be taken as the output of two hours of pouring.

2.2.5 Where 2.2.4 applies and production is carefully monitored by systematic checking of the melting process by, for example, chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals as agreed by the Surveyor.

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 5), the specified tensile strength is to be not less than 200 N/mm^2 subject to any additional requirements of the relevant Rules. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

■ *Section 3* Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.1 This Section gives the specific requirements for spheroidal or nodular graphite iron castings.

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in 3.4.2.

3.2 Heat treatment

3.2.1 The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test are to undergo a ferritising heat treatment, *see* 3.4.2.

3.3 Test material

3.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3 The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

3.3.2 The test samples may be either gated to the casting or separately cast.

3.3.3 Where separately cast test samples are used, they are to be taken towards the end of pouring of the castings.

3.4 Mechanical tests

3.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.3.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.3.1 and are intended for information purposes.

3.4.2 Impact tests may be required for some applications in which case the selection of the grade is to be confined to those listed in Table 7.3.2. These castings are to be given a ferritising heat treatment. The mechanical test results are to comply with Table 7.3.2.

3.4.3 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 7.3.1 and 7.3.2 but subject to any additional requirements of the relevant Rules.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u	25	12	50	75
v	55	40	90	125
x	40	30	60	65
y	100	80	150	165
Z	To suit testing machine			
Rs	Approximately 5			

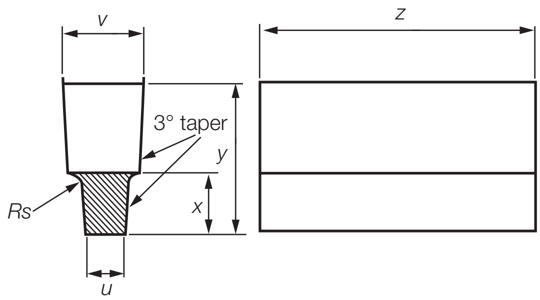


Fig. 7.3.1 Type A (U-type) test samples

Dimension	Standard sample, mm
u	25
v	90
x	40
y	100
Z	To suit testing machine
Rs	Approximately 5

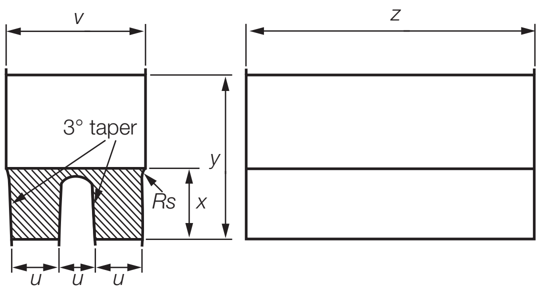


Fig. 7.3.2 Type B (Double U-type) test samples

3.5 Metallographic examination

3.5.1 Samples for metallographic examination are to be prepared for spheroidal or nodular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

3.5.2 Examination of the samples is to show that at least 90 per cent of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.1 and are intended for information purposes.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u *v* *x* *y*	25 55 40 140	12 40 25 135	50 100 50 150	75 125 65 175
Z	To suit testing machine			
Minimum thickness of mould surrounding test sample	40	40	80	80

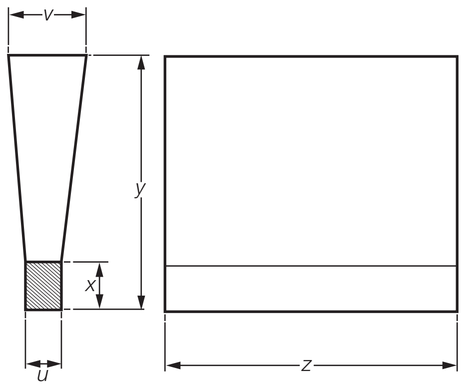


Fig. 7.3.3 Type C (Y-type) test samples

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 3.4.1)	Typical structure of matrix (*see* 3.5.2)
370	230	17	120 – 180	Ferrite
400	250	12	140 – 200	Ferrite
500	320	7	170 – 240	Ferrite/pearlite
600	370	3	190 – 270	Pearlite/ferrite
700	420	2	230 – 300	Pearlite
800	480	2	250 – 350	Pearlite or tempered structure

NOTE
Proof stresses need only be determined if specifically requested.

Table 7.3.2 Mechanical properties: special qualities

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*see* Note 1) N/mm^2	Elongation on $5,65\sqrt{S_o}$ minimum % (*see* Note 2)	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*see* Note 3)	Average energy J minimum (*see* Note 4)
350	220	22	110 – 170	20 –40	17 (14) 12 (10)
400	250	18	140 – 200	20 –20	14 (11) 12 (10)

NOTES
1. Proof stresses need only be determined if specifically requested.
2. In the case of integrally cast samples, the acceptable elongation may be taken as 2 percentage points less.
3. Tests need only be made at either of the temperatures listed, as appropriate.
4. The average value measured on three Charpy V-notch specimens. One of the three values may be below the specified minimum average value, but not less than the value shown in brackets.
5. Typical structure of the matrix is ferrite.

Section 4 Compacted or vermicular graphite iron castings

4.1 Scope

4.1.1 This Section gives the specific requirements for compacted or vermicular graphite iron castings.

4.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures.

4.2 Heat treatment

4.2.1 Where castings do not meet the specified mechanical property requirements in the as-cast condition, a corrective heat treatment may be carried out. This is to be restricted to a single heat treatment and the test coupons must be heat treated with the castings.

4.3 Test material

4.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3. The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially agreed with the Surveyor.

4.3.2 The test samples may be either gated to the casting or separately cast.

4.4 Mechanical tests

4.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.4.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.4.1 and are intended for information purposes.

4.4.2 Castings may be supplied to any specified minimum tensile strength grade.

Table 7.4.1 Mechanical properties for acceptance purposes: compacted or vermicular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 4.4.1)	Typical structure of matrix (*see* 4.5.2)
300	210	2	140 – 210	Ferrite
350	245	1,5	160 – 220	Ferrite/pearlite
400	280	1	180 – 240	Pearlite/ferrite
450	315	1	200 – 250	Pearlite
500	350	0,5	220 – 260	Fully pearlitic

NOTE
Proof stresses need only be determined if specifically requested.

4.5 Metallographic examination

4.5.1 Samples for metallographic examination are to be prepared for compacted or vermicular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

4.5.2 Examination of the samples is to show that at least 80 per cent of the graphite is in a dispersed, compacted or vermicular form. The remaining 20 per cent of the graphite may be in spheroidal forms. Details of typical matrix structures are given in Table 7.4.1 and are intended for information purposes.

■ *Section 5* Iron castings for crankshafts

5.1 Scope

5.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors. For both of these applications, details of the proposed specification are to be submitted for approval.

5.1.2 Crankshaft castings in grey iron and compacted graphite iron are acceptable only for compressors, and the specified minimum tensile strength is to be not less than 300 N/mm^2.

5.1.3 For crankshaft castings in spheroidal or nodular graphite iron, the specified minimum tensile strength is to be not less than 370 N/mm^2.

5.2 Manufacture

5.2.1 Details of the method of manufacture, including the arrangements proposed for the provision of test material, are to be submitted for approval.

5.2.2 Tests to demonstrate the soundness of prototype castings and the mechanical properties at important locations will be required.

5.3 Heat treatment

5.3.1 In general, crankshaft castings other than those which are fully annealed, normalised or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

5.3.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests, and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

5.4 Test material

5.4.1 Unless otherwise approved, the dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.

5.4.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from, each casting.

5.4.3 The batch testing procedure detailed in 1.6.2 may be adopted only where small and identical crankshaft castings are produced in quantity. Generally, the fettled mass of each casting in a batch is not to exceed 100 kg, and in addition to tensile tests, the hardness of each casting is to be determined. For this purpose, a small flat is to be ground on each crankshaft, and Brinell hardness tests are to be carried out. The results obtained from these tests are to comply with the approved specification.

5.5 Non-destructive examination

5.5.1 Cast crankshafts are to be subjected to a full magnetic particle or dye penetrant examination after final machining and completion of any surface hardening operations.

5.5.2 Particular attention is to be given to the testing of the pins, journals and associated fillet radii.

5.5.3 Cracks and crack-like defects are not acceptable. Fillet radii are to be free from any indications.

5.6 Rectification of defective castings

5.6.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

5.7 Certification of materials

5.7.1 The chemical composition of ladle samples is to be given in addition to the other particulars detailed in 1.12.2.

Section

■ *Section 1* Plates, bars and sections

1.1 Scope

1.1.1 This Section makes provision for aluminium alloy plates, bars and sections intended for use in the construction of ships and other marine structures and for cryogenic applications.

1.1.2 Except as provided in 1.1.4, all items are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and those detailed in this Section.

1.1.3 The thickness of plates, sections and bars described by these requirements will be in the range between 3 and 50 mm. Plates and sections less than 3,0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

1.1.4 Plates less than 3,0 mm thick and sections less than 40 mm x 40 mm x 3,0 mm may be manufactured and tested in accordance with the requirements of an acceptable National specification.

1.1.5 Where the section thickness exceeds 50 mm, the requirements will be subject to special consideration.

1.1.6 Materials intended for the construction of cargo tanks or storage for liquefied gases, and for other low temperature applications, are to be manufactured in the 5083 alloy in the annealed condition.

1.1.7 As an alternative to 1.1.2 and 1.1.4, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section and are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 Aluminium alloys are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or drawing.

1.2.3 All melts are to be suitably degassed prior to casting such that the aim hydrogen content is less than 0,2 ml per 100 g.

1.3 Quality of materials

1.3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

1.3.2 The manufacturer is to verify the integrity of pressure welds of closed extrusion profiles in accordance with 1.10.

Table 8.1.1 Underthickness tolerances for rolled products for marine construction

Nominal thickness range, mm	Underthickness tolerance for nominal width range, mm		
	≤1500	>1500 ≤2000	>2000 ≤3500
≥3,0 <4,0	0,10	0,15	0,15
≥4,0 <8,0	0,20	0,20	0,25
≥8,0 <12	0,25	0,25	0,25
≥12 <20	0,35	0,40	0,50
≥20 <50	0,45	0,50	0,65

1.4 Dimensional tolerances

1.4.1 Underthickness tolerances for rolled products for marine construction are given in Table 8.1.1.

1.4.2 Underthickness tolerances for extruded products are to comply with an acceptable National or International Standard.

1.4.3 There are to be no underthickness tolerances for materials for application in cryogenic process pressure vessels.

1.4.4 Dimensional tolerances other than permitted underthicknesses are to comply with an acceptable National or International Standard.

1.4.5 Verification of dimensions is the responsibility of the manufacturer. Acceptance by Surveyors of material which is later found to be defective does not absolve the manufacturer from this responsibility.

Table 8.1.2 Chemical composition, percentage

Element	5083	5383	5059	5086	5754	5456	6005–A (*see* Note 1)	6061 (*see* Note 1)	6082
Copper	0,10 max.	0,20 max.	0,25 max.	0,10 max.	0,10 max.	0,10 max.	0,30 max.	0,15—0,40	0,10 max.
Magnesium	4,0—4,9	4,0—5,2	5,0—6,0	3,5—4,5	2,6—3,6	4,7—5,5	0,40—0,70	0,80—1,20	0,60—1,20
Silicon	0,40 max.	0,25 max.	0,45 max.	0,40 max.	0,40 max.	0,25 max.	0,50—0,90	0,40—0,80	0,70—1,30
Iron	0,40 max.	0,25 max.	0,50 max.	0,50 max.	0,40 max.	0,40 max.	0,35 max.	0,70 max.	0,50 max.
Manganese	0,40—1,00	0,7—1,0	0,6—1,2	0,20—0,70	0,50 max. (*see* Note 2)	0,50—1,00	0,50 max. (*see* Note 3)	0,15 max.	0,40—1,00
Zinc	0,25 max.	0,40 max.	0,40—0,90	0,25 max.	0,20 max.	0,25 max.	0,20 max.	0,25 max.	0,20 max.
Chromium	0,05—0,25	0,25 max	0,25 max.	0,05—0,25	0,30 max. (*see* Note 2)	0,05—0,20	0,30 max. (*see* Note 3)	0,04—0,35	0,25 max.
Titanium	0,15 max.	0,15 max.	0,20 max.	0,15 max.	0,15 max.	0,20 max.	0,10 max.	0,15 max.	0,10 max.
Zirconium		0,20 max.	0,05—0,25						
Other elements: each	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. Mn + Cr = 0,10 min., 0,60 max.
3. Mn + Cr = 0,12 min., 0,50 max.

1.5 Chemical composition

1.5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

1.5.2 The chemical composition of these samples is to comply with the requirements of Table 8.1.2.

1.6 Heat treatment

1.6.1 The Aluminium 5000 series alloys, capable of being strain hardened, are to be supplied in any of the following temper conditions:

- O annealed
- H111 annealed with slight strain hardening
- H112 strain hardened from working at elevated temperatures
- H116 strain hardened and with specified resistance to exfoliation corrosion for alloys where the magnesium content is 4 per cent or more
- H321 strain hardened and stabilised.

1.6.2 The H116 temper is specially developed for use in a marine environment.

1.6.3 The Aluminium 6000 series alloys, capable of being age hardened, are to be supplied in either of the following temper conditions:

- T5 hot worked and artificially aged
- T6 solution treated and artificially aged.

1.7 Test material

1.7.1 Materials of the same product form, (i.e., plates, sections or bars) and thickness and from a single cast or equivalent, are to be presented for test in batches of not more than 2 tonnes, with the exceptions of those given in 1.7.2, 1.7.3 and 1.7.4.

1.7.2 For single plates or coils weighing more than 2 tonnes, only one tensile specimen per plate or coil is to be taken.

1.7.3 A tensile test specimen is required from each plate to be used in the construction of cargo tanks, secondary barriers and process pressure vessels with design temperatures below –55°C.

1.7.4 Extrusions, bars and sections of less than 1 kg/m in nominal weight are to be tested in batches of 1 tonne. Where the nominal weight is greater than 5 kg/m, one tensile test is to be carried out for every three tonnes produced, or fractions thereof.

1.7.5 If the material is supplied in the heat treated condition, each batch is to be treated together in the same furnace or subjected to the same finishing treatment when a continuous furnace is used.

1.7.6 For plates over 300 mm in width, tensile test specimens are to be cut with their length transverse to the principal direction of rolling. For narrow plates and for sections and bars, the test specimens are to be cut in the longitudinal direction. Longitudinal tensile test specimens are accepted for the strain hardenable 5000 series alloys.

Table 8.1.3 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloy products

Alloy and temper condition, *see* Note 3	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation 4d, %	Elongation on $5{,}65\sqrt{S_o}$ 5d,%
5083-O	$3 \le t \le 50$ (*see* Note 2)	125	275–350	16	14
5083-H111	$3 \le t \le 50$	125	275–350	16	14
5083-H112	$3 \le t \le 50$	125	275	12	10
5083-H116	$3 \le t \le 50$	215	305	10	10
5083-H321	$3 \le t \le 50$	215–295	305–380	12	10
5086-O	$3 \le t \le 50$	100	240–305	16	14
5086-H111	$3 \le t \le 50$	100	240–305	16	14
5086-H112	$3 \le t \le 12{,}5$ $12{,}5 < t \le 50$	125 105	250 240	8 —	— 9
5086-H116	$3 \le t \le 50$	195	275	10 (*see* Note 1)	9
5059-O	$3 \le t \le 50$	160	330	24	24
5059-H111	$3 \le t \le 50$	160	330	24	24
5059-H116	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5059-H321	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5754-H111	$3 \le t \le 50$	80	190–240	18	17
5383-H116	$3 \le t \le 50$	220	305	10	10
5383-H321	$3 \le t \le 50$	220	305	10	10
5456-O	$3 \le t \le 6{,}3$ $6{,}3 \le t \le 50$	130–205 125–205	290–365 285–360	16 16	— 14
5456-H116	$3 \le t \le 30$ $30 < t \le 40$ $40 < t \le 50$	230 215 200	315 305 285	10 — —	10 10 10
5456-H321	$3 \le t \le 12{,}5$ $12{,}5 \le t \le 40$ $40 \le t \le 50$	230–315 215–305 200–295	315–405 305–385 285–370	12 — —	— 10 10
5754-O	$3 \le t \le 50$	80	190–240	18	17

NOTES
1. 8% for thickness up to and including 6,3 mm.
2. For application to liquefied natural gas carriers or liquefied natural gas tankers where thicknesses are in excess of 50 mm, the mechanical properties given in this table are, in general, to be complied with.
3. The mechanical properties for the O and H111 tempers are the same for all alloys shown in this Table. However, they are separated in this Table as they are made using different manufacturing processes.

Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected extruded aluminium alloy products

Alloy and temper condition, *see* Note 2	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation 4d, %	Elongation on $5{,}65\sqrt{S_o}$ 5d,%
5083-O	$3 \le t \le 50$	110	270–350	14	12
5083-H111	$3 \le t \le 50$	165	275	12	10
5083-H112	$3 \le t \le 50$	110	270	12	10
5086-O	$3 \le t \le 50$	95	240–315	14	12
5086-H111	$3 \le t \le 50$	145	250	12	10
5086-H112	$3 \le t \le 50$	95	240	12	10
5059-H112	$3 \le t \le 50$	200	330	10	10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H112	$3 \le t \le 50$	190	310	13	13
6005A-T5	$3 \le t \le 50$	215	260	9	8
6005A-T6	$3 \le t \le 10$ $10 < t \le 50$	215 200	260 250	8 8	6 6
6061-T6	$3 \le t \le 50$	240	260	10	8
6082-T5	$3 \le t \le 50$	230	270	8	6
6082-T6	$3 \le t \le 5$ $5 < t \le 50$	250 260	290 310	6 10	— 8

NOTES
1. The values are applicable for longitudinal and transverse tensile test specimens as well.
2. The mechanical properties for the O and H111 tempers are the same for all alloys shown in this Table. However, they are separated in this Table as they are made using different manufacturing processes.

1.7.7 Longitudinal tensile test specimens from a plate are to be taken at 1/3 width from the longitudinal edge. Longitudinal tensile test specimens taken from extruded sections should be taken in the range from 1/3 to 1/2 of the distance from the edge to the centre of the thickest region of the section.

1.8 Mechanical tests

1.8.1 At least one tensile test specimen is to be prepared from each batch of material submitted for acceptance.

1.8.2 Tensile test specimens are to be machined to the dimensions given in Fig. 2.2.3 in Chapter 2. Alternatively, machined proportional test specimens of circular cross-section in accordance with Fig. 2.2.2 in Chapter 2 may be used provided that the diameter is not less than 10 mm. Round bars may be tested in full section, or test specimens may be machined in accordance with the dimensions given in Fig. 2.2.2 in Chapter 2.

1.8.3 The results of all tensile tests are to comply with the values given in Tables 8.1.3 and 8.1.4, as applicable.

1.9 Corrosion tests

1.9.1 Rolled 5000 series alloys of type 5083, 5383, 5059, 5456 and 5086 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications with frequent direct contact with seawater are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x under the conditions specified in ASTM B928 Section 9.4.1, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to

intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production practices are not to be changed after approval of the reference micrographs.

1.9.3 For batch acceptance of 5000 series alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination, under the conditions specified in ASTM B928 Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 (ASSET) test, and the sample is to exhibit resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2 when subjected to ASTM G67 (NAMLT) test. If the results from testing satisfy the acceptance criteria stated in 1.9.2, the batch is accepted, otherwise it is to be rejected.

1.9.4 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B298, or equivalent standards. If this alternative is used, then the results of the test must satisfy the acceptance criteria stated in 1.9.2.

1.9.5 Tempers that are corrosion tested in accordance with 1.9.3 are to be marked ‘M’ after the temper condition, e.g., 5083 H321 M.

1.10 Pressure weld tests

1.10.1 The integrity of pressure welds of closed profile extrusions is to be verified by examination of macrosections or drift expansion tests.

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends after final heat treatment.

1.10.3 Where verification is by examination of macrosections, no indication of lack of fusion is permitted.

1.10.4 Where verification of fusion at pressure welds of closed profile extrusions is by drift expansion test, testing is to be generally in accordance with Ch 2,4.3. The minimum included angle of the mandrel is to be 60°, and the minimum specimen length, 50 mm. For acceptance, there is to be no failure by a clean split along the weld line.

1.11 Visual and non-destructive examination

1.11.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.11.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.11.3 For applications where the non-destructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

1.12 Rectification of defects

1.12.1 Slight surface imperfections may be removed by mechanical means, provided that the prior agreement of the Surveyor is obtained, that the work is carried out to his satisfaction and that the final dimensions are acceptable. The repair of defects by welding is not allowed.

1.13 Identification

1.13.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

1.13.2 Products are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) Manufacturer’s name or trade mark.
(b) Alloy grade and temper condition.
(c) Identification mark which will enable the full history of the item to be traced.
(d) The stamp of the LR brand, .

1.14 Certification of materials

1.14.1 A manufacturer’s certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.14.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Contract number.
(c) Address to which material is to be despatched.
(d) Description and dimensions.
(e) Alloy grade and temper condition.
(f) Identification mark which will enable the full history of the item to be traced.
(g) Chemical composition.
(h) Mechanical test results (not required on shipping statement).
(j) Details of temper condition and heat treatment, where applicable.
(k) Corrosion test results (as applicable).

1.14.3 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the manufacturer of the alloy stating the cast number and chemical composition. The works at which the alloy was produced must be approved by LR.

■ *Section 2* Aluminium alloy rivets

2.1 Scope

2.1.1 Provision is made in this Section for aluminium alloy rivets intended for use in the construction of marine structures.

2.1.2 They are to be manufactured and tested in accordance with the appropriate requirements of Section 1 and those detailed in this Section.

2.2 Chemical composition

2.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.2.1.

Table 8.2.1 Chemical composition, percentage

Element	5154A	6082
Copper	0,10 max.	0,10 max.
Magnesium	3,1 – 3,9	0,6 – 1,2
Silicon	0,50 max.	0,7 – 1,3
Iron	0,50 max.	0,50 max.
Manganese	0,1 – 0,5	0,4 – 1,0
Zinc	0,20 max.	0,20 max.
Chromium	0,25 max.	0,25 max.
Titanium	0,20 max.	0,10 max.
Other elements: each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder

2.3 Heat treatment

2.3.1 Rivets are to be supplied in the following condition:

5154A – annealed
6082 – solution treated.

2.4 Test material

2.4.1 Bars intended for the manufacture of rivets are to be presented for test in batches of not more than 250 kg. The material in each batch is to be the same diameter and nominal chemical composition.

2.4.2 At least one test sample is to be selected from each batch and, prior to testing, is to be heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

2.5 Mechanical tests

2.5.1 At least one tensile and one dump test specimen are to be prepared from each test sample.

2.5.2 The tensile test specimen may be either a suitable length of bar tested in full cross-section or a specimen machined to the dimensions given in Fig. 2.2.2 in Chapter 2.

2.5.3 The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis. The length of this section is to be equal to the diameter of the bar.

2.5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.2.2.

Table 8.2.2 Mechanical properties for acceptance purposes

Mechanical properties	5154A	6082
0,2% proof stress N/mm^2 min.	90	120
Tensile strength N/mm^2 min.	220	190
Elongation on $5{,}65\sqrt{S_o}$ % min.	18	16

2.5.5 The dump test is to be carried out at ambient temperature and is to consist of compressing the specimen until the diameter is increased to 1,6 times the original diameter. After compression, the specimen is to be free from cracks.

2.6 Tests from manufactured rivets

2.6.1 At least three samples are to be selected from each consignment of manufactured rivets. Dump tests as detailed in 2.5 are to be carried out on each sample.

2.7 Identification

2.7.1 Each package of manufactured rivets is to be identified with attached labels giving the following details:
(a) Manufacturer's name or trade mark.
(b) Alloy grade.
(c) Rivet size.

2.8 Certification of materials

2.8.1 A manufacturer's certificate is to be issued (*see* Ch 1,3.1) and for each consignment of manufactured rivets is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Specification.

■ *Section 3*
Aluminium alloy castings

3.1 Scope

3.1.1 Provision is made in this Section for aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures and liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping systems outside cargo tanks except for short lengths of pipes attached to the cargo tanks in which case fire-resisting insulation should be provided.

3.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2 and also with the requirements of this Section.

3.1.3 As an alternative to 3.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.2 Manufacture

3.2.1 Castings are to be manufactured at foundries approved by LR.

3.3 Quality of castings

3.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.4 Chemical composition

3.4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 8.3.1. Suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

Table 8.3.1 Chemical composition, percentage

Alloy / Element	Al–Mg 3	Al–Si 12	Al–Si 10 Mg	Al–Si 7 High purity
Copper	0,1 max.	0,1 max.	0,1 max.	0,1 max.
Magnesium	2,5—4,5	0,1 max.	0,15—0,4	0,25—0,45
Silicon	0,5 max.	11,0—13,5	9,0—11,0	6,5—7,5
Iron	0,5 max.	0,7 max.	0,6 max.	0,2 max.
Manganese	0,6 max.	0,5 max.	0,6 max.	0,1 max.
Zinc	0,2 max.	0,1 max.	0,1 max.	0,1 max.
Chromium	0,1 max.	—	—	—
Titanium	0,2 max.	0,2 max.	0,2 max.	0,2 max.
Others each	0,05 max.	0,05 max.	0,05 max.	0,05 max.
Total	0,15 max.	0,15 max.	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder	Remainder	Remainder

3.4.2 Where it is proposed to use alloys not specified in Table 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

3.5 Heat treatment

3.5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3	–	as-manufactured
Grade Al-Si 12	–	as-manufactured
Grade Al-Si 10 Mg	–	as-manufactured or solution heat treated and precipitation hardened
Grade Al-Si 7 Mg (high purity)	–	solution heat treated and precipitation hardened.

3.6 Mechanical tests

3.6.1 At least one tensile specimen is to be tested from each cast and, where heat treatment is involved, for each heat treatment batch from each cast. Where continuous melting is employed, 500 kg of fettled castings may be regarded as a cast.

3.6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

3.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

3.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

3.6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 8.3.2 and/or Table 8.3.3.

Table 8.3.2 Minimum mechanical properties for acceptance purposes of sand-cast and investment cast reference test pieces

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	150	3
Al–Si 10 Mg	M	150	2
Al–Si 10 Mg	TF	220	1
Al–Si 7 Mg	TF	230	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

Table 8.3.3 Minimum mechanical properties for acceptance purposes of chill-cast reference test piece

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	170	3
Al–Si 10 Mg	M	170	3
Al–Si 10 Mg	TF	240	1,5
Al–Si 7 Mg	TF	250	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.6.6 Where the results of a test do not comply with the requirements, the re-test procedure detailed in Ch 2,1.4 is to be applied. Where castings are to be used in the heat treated condition, the re-test sample must have been heat treated together with the castings it represents.

3.7 Visual examination

3.7.1 All castings are to be cleaned and adequately prepared for inspection.

3.7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

3.7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

3.8 Rectification of defective castings

3.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

3.8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

3.9 Pressure testing

3.9.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

3.10 Identification

3.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

3.10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:
(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for the inspection.
(d) Test pressure where applicable.
(e) Date of final inspection.

3.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

3.11 Certification of materials

3.11.1 A LR certificate is to be issued (*see* Ch 1,3.1) giving the following particulars for each casting or batch of castings which have been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and alloy type.
(c) Identification number.
(d) Ingot or cast analysis.
(e) General details of heat treatment, where applicable.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

■ *Section 4* Aluminium/steel transition joints

4.1 Scope

4.1.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating.

4.1.2 Each individual application is to be separately approved as required by the relevant Rules dealing with design and construction.

4.2 Manufacture

4.2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.2.2 The aluminium material is to comply with the requirements of Section 1 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2.

4.2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 4.2.2 or are approved for a specific application.

4.2.4 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.3 Visual and non-destructive examination

4.3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National Standard to determine the extent of any unbonded areas. Unbonded areas are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

4.4 Mechanical tests

4.4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on the bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to the maximum allowable interface temperature, *see* 4.2.1; the other two specimens are to be tested without heat treatment.

4.4.2 Shear tests may be made on a specimen as shown in Fig. 8.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig. 8.4.2 or by an appropriate alternative method.

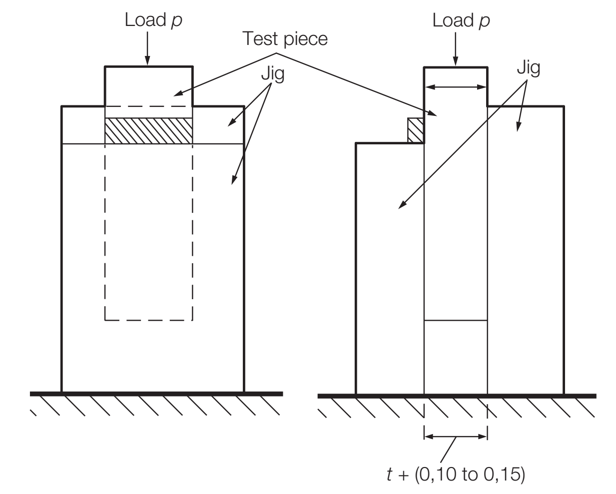


Fig. 8.4.1 Specimen and procedure for shear tests

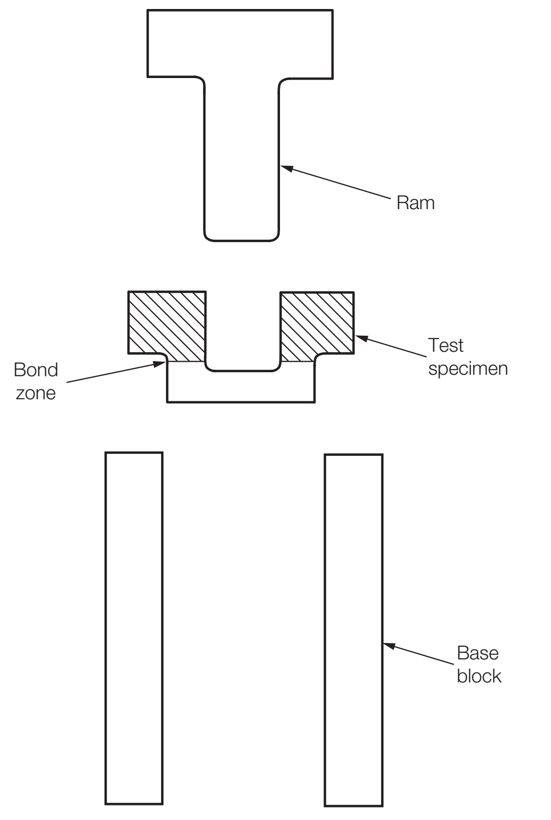


Fig. 8.4.2 Ram tensile test

4.4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

4.4.4 If either the shear or tensile strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition, bend tests as described in 4.4.6 and Table 8.4.1 are to be made.

Table 8.4.1 Bend tests on explosion bonded aluminium/steel composites

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3*T*
Steel in tension	90	3*T*
Side bend	90	6*T*
NOTE *T* is the total thickness of the composite plate.		

4.4.5 If either the shear or tensile strength of the bond is less than 70 per cent of the specified minimum the cause is to be investigated. After evaluation of the results of this investigation, LR will consider the extent of composite plate which is to be rejected.

4.4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 8.4.1:
(a) The aluminium plate is in tension.
(b) The steel plate is in tension.
(c) A side bend is applied.

4.5 Identification

4.5.1 Each acceptable transition strip is to be clearly marked with the following particulars:
(a) LR or Lloyd's Register and the abbreviated name of LR's local office.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the grade of aluminium.
(d) Identification mark for the grade of steel.
The particulars are to be stamped on the aluminium surface at one end of the strip.

4.6 Certification of materials

4.6.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and as a minimum is to include the following particulars:
(a) Purchaser's name and order number.
(b) The contract number for which the material is intended, if known.
(c) Address to which the material is dispatched.
(d) Description and dimensions of the material.
(e) Specifications or grades of both the aluminium alloy and the steel and any intermediate layer.
(f) Cast numbers of the steel and aluminium plates.
(g) Identification number of the composite plate.
(h) Mechanical test results (not required on shipping statement).

Section

■ *Section 1* Castings for propellers

1.1 Scope

1.1.1 This Section gives the requirements for copper alloy castings for one-piece propellers and separately cast blades and bosses for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers and propulsors fitted to podded drives and azimuth units.

1.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and the specific requirements of this Section.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application.

1.1.4 The appropriate requirements of this Section may also be applied to the repair and inspection of propellers which have been damaged during service.

1.1.5 Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 All castings are to be manufactured at foundries approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to avoid turbulent flow. Special devices and/or procedures are to be used to prevent slag flowing into the mould.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.3.2 The removal and repair of defects are dealt with in 1.9 and 1.10.

1.4 Chemical composition

1.4.1 The chemical compositions of samples from each melt are to comply with the manufacturing specification approved by LR and also with the overall limits given in Table 9.1.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that any harmful residual elements are within acceptable limits.

1.4.2 The use of alloys whose chemical compositions are different from those detailed in Table 9.1.1 will be given special consideration by LR.

1.4.3 The manufacturer is to maintain records of all chemical analyses, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

Table 9.1.1 Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu 1 Manganese bronze (high tensile brass)	52–62	1,5 max.	35–40	0,5 max.	1,0 max.	0,5–2,5	0,5–3,0	0,5–4,0
Grade Cu 2 Ni-manganese bronze (high tensile brass)	50–57	0,1–1,5	33–38	0,5 max.	3,0–8,0	0,5–2,5	0,5–2,0	1,0–4,0
Grade Cu 3 Ni-aluminium bronze	77–82	0,1 max.	1,0 max.	0,03 max.	3,0–6,0 (*see* Note)	2,0–6,0 (*see* Note)	7,0–11,0	0,5–4,0
Grade Cu 4 Mn–aluminium bronze	70–80	1,0 max.	6,0 max.	0,05 max.	1,5–3,0	2,0–5,0	6,5–9,0	8,0–20,0

NOTE
For Naval ships, the nickel content is to be higher than the iron content.

1.4.4 When a melt is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor. If any foundry returns are added to the melts, the ingot manufacturer's chemical analyses are to be supplemented by frequent checks as required by the Surveyor.

1.4.5 For alloys Grade Cu 1 and Cu 2, the zinc equivalent shall not exceed 45 per cent, and is to be calculated using the following formula:

$$\text{zinc equivalent \%} = 100 - \frac{100 \times \%\text{Cu}}{100 + A}$$

where A is the algebraic sum of the following:

1 x % Sn
5 x % Al
–0,5 x % Mn
–0,1 x % Fe
–2,3 x % Ni

1.4.6 Samples for metallographic examination are to be prepared from the ends of test bars cast from every melt of Grade Cu 1 and Cu 2 alloys. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 per cent.

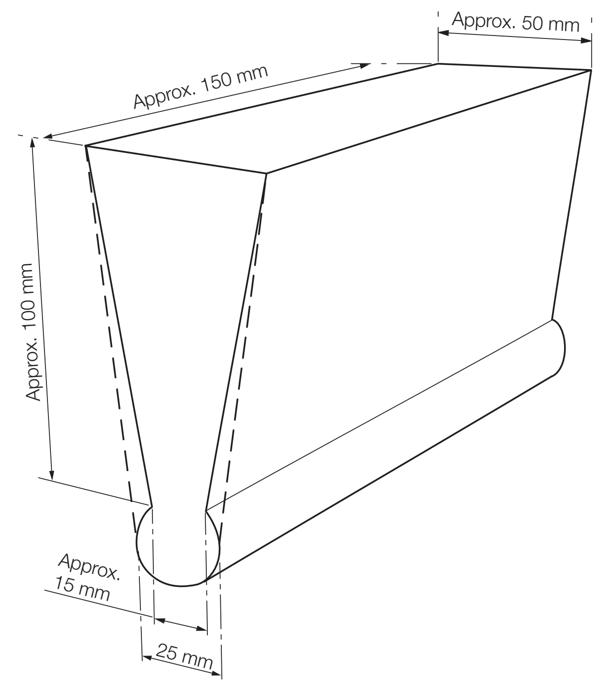


Fig. 9.1.1 Keel block type test sample

1.5 Heat treatment

1.5.1 At the option of the manufacturer, castings may be supplied in the 'as-cast' or heat treated condition. However, if heat treatment is to be applied, full details are to be included in the manufacturing specification.

1.5.2 If any welds are made in the propeller casting, stress relief heat treatment is required in order to minimise the residual stresses. Requirements concerning such heat treatment are given in 1.10.

1.6 Test material

1.6.1 Test samples are to be cast separately from each melt used for the manufacture of propeller or propeller blade castings.

1.6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 9.1.1 and are to be cast in moulds made from the same type of material as used for the castings.

1.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be transferred and maintained during the preparation of test specimens.

1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

1.7 Mechanical tests

1.7.1 At least one tensile test specimen representative of each cast is to be prepared. The dimensions of this test specimen are to be in accordance with Fig. 2.2.1 in Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Table 9.1.2.

1.7.3 The mechanical properties of alloys whose chemical compositions do not accord with Table 9.1.1 are to comply with a manufacturing specification approved by LR.

Table 9.1.2 Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Grade Cu 1 Manganese bronze (high tensile brass)	175	440	20
Grade Cu 2 Ni-manganese bronze (high tensile brass)	175	440	20
Grade Cu 3 Ni-aluminium bronze	245	590	16
Grade Cu 4 Mn-aluminium bronze	275	630	18

1.8 Inspection and non-destructive examination

1.8.1 Propeller castings should be visually inspected at all stages of manufacture. The manufacturer is to draw any significant imperfections to the attention of the Surveyor. Such imperfections are to be verified in accordance with 1.9.

1.8.2 All finished castings are to be subjected to a comprehensive visual examination by the Surveyor, including internal surfaces such as the bore and bolt holes. Where unauthorised weld repairs are suspected by the Surveyor, the area is to be etched (e.g., by iron chloride) for the purpose of confirmation.

1.8.3 For the purpose of these requirements, the blades of propellers, including CPP blades, are divided into three severity Zones A, B and C as shown in Fig. 9.1.2 and detailed in 1.8.4 for blades having skew angles of 25° or less and 1.8.5 for blades having skew angles of greater than 25°.

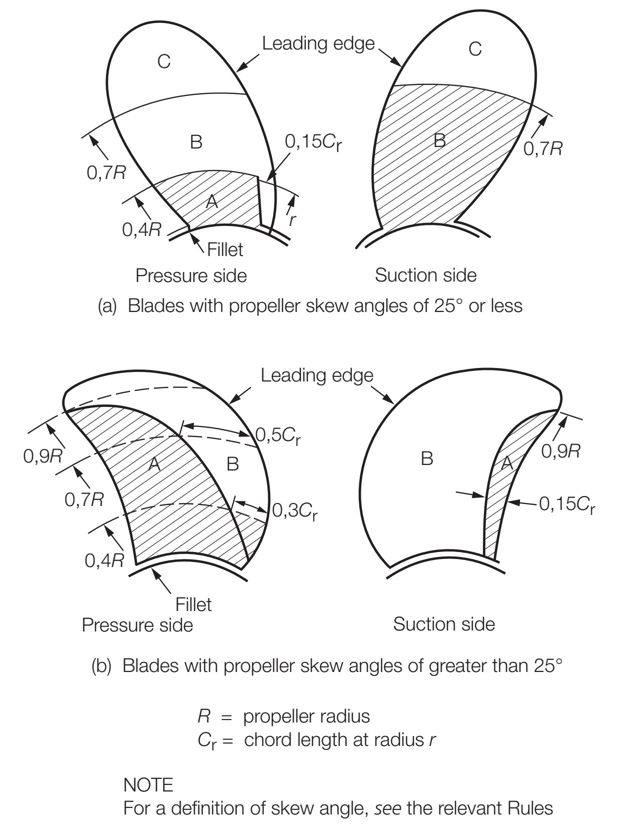


Fig. 9.1.2 Severity zones in all propeller blades

1.8.4 **Skew angles of 25° or less:**

- Zone A is the area on the pressure side of the blade from and including the root fillet to 0,4*R* and bounded by the trailing edge and by a line at a distance 0,15 times the chord length from the leading edge.
- Zone B includes the areas inside 0,7*R* on both sides of the blade, excluding Zone A.
- Zone C includes the areas outside 0,7*R* on both sides of the blade.

1.8.5 **Skew angles of greater than 25°**:

- Zone A is the area on the pressure side of the blade bounded by, and including, the root fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0,9*R* and passing through the mid-point of the chord at 0,7*R* and a point situated at 0,3 of the chord length from the leading edge at 0,4*R*.
- Zone A also includes the area along the trailing edge on the suction side of the blade from the root to 0,9*R* and with its inner boundary at 0,15 of the chord length tapering to meet the trailing edge at 0,9*R*.
- Zone B constitutes the whole of the remainder of the blade surfaces.

1.8.6 In propeller blades with continuously loaded tips (CLT), the whole of the tip plate and the adjoining blade to a distance of 100 mm is to be regarded as severity Zone B, *see* Fig. 9.1.3. For propellers with diameters less than 2 m, the width of this zone may be reduced to one tenth of the propeller radius.

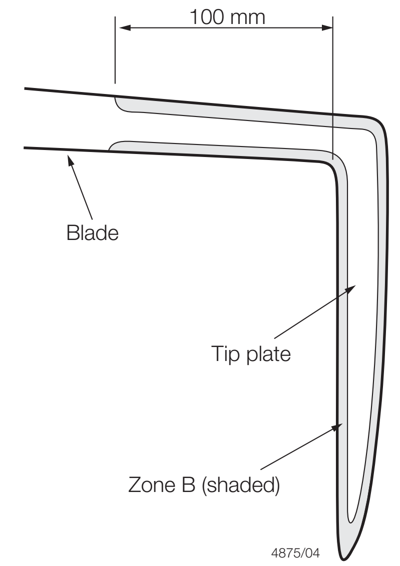
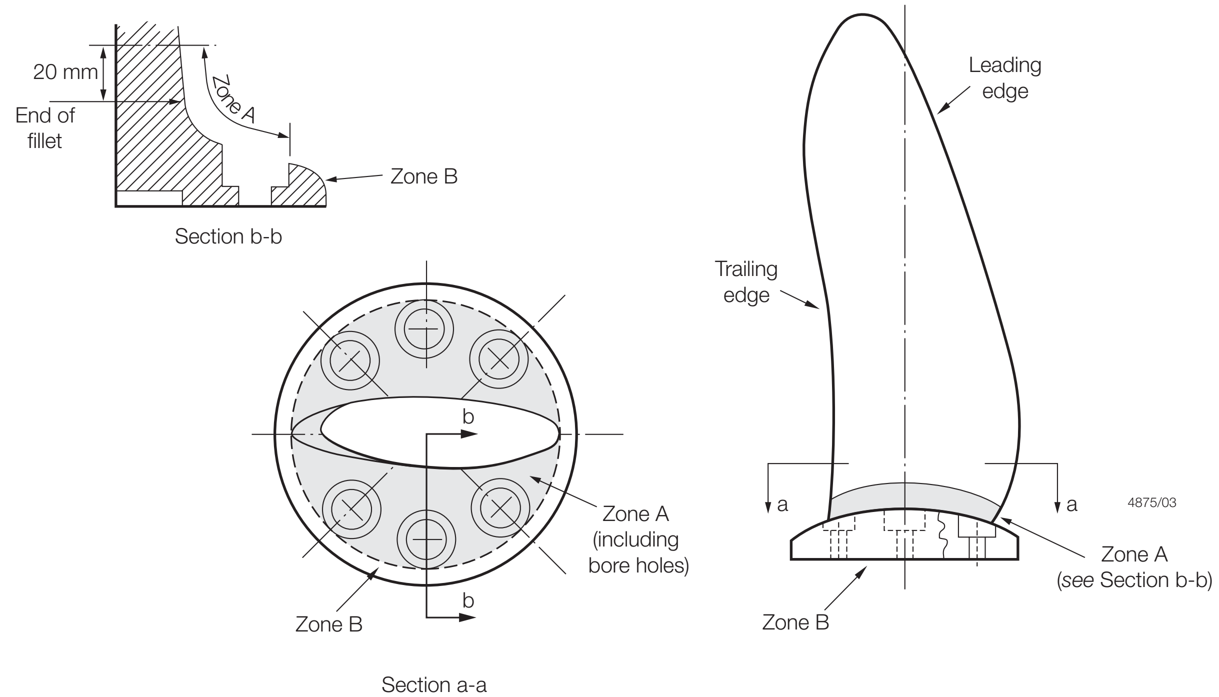


Fig. 9.1.3
Severity Zone B at Continuously loaded blade tip

1.8.7 In addition, the palm of a CPP blade is divided into severity Zones A and B as shown in Fig. 9.1.4.

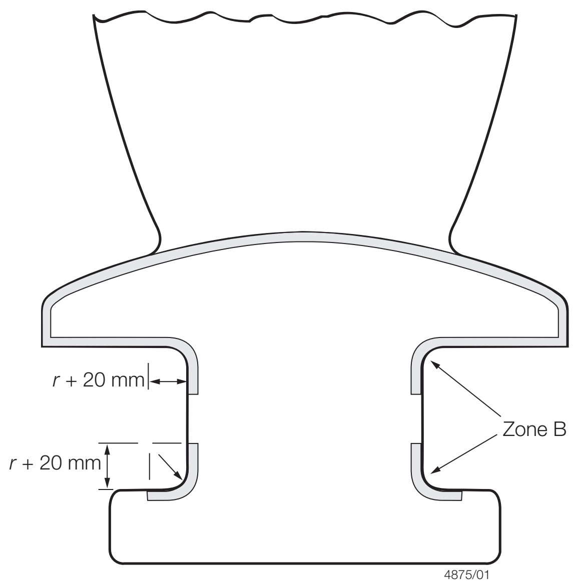
1.8.8 If a CPP blade has an integrally cast journal, the fillets of the journal and the adjoining material up to a distance of 20 mm from the fillet run-outs are to be regarded as Zone B, as indicated in Fig. 9.1.5. The remainder of the surface of the journal may be regarded as Zone C.

1.8.9 Hubs of controllable pitch propellers are to contain a Zone A region at each blade port as shown in Fig. 9.1.6. The remainder may be regarded as Zone C.



The surfaces of blades are to be divided into severity zones in accordance with Fig. 9.1.2

Fig. 9.1.4 Severity zones for controllable pitch propeller blades



The surfaces of the journal which are not shaded are to be regarded as severity Zone C

Fig. 9.1.5
Severity zones in integrally cast CPP blade journals

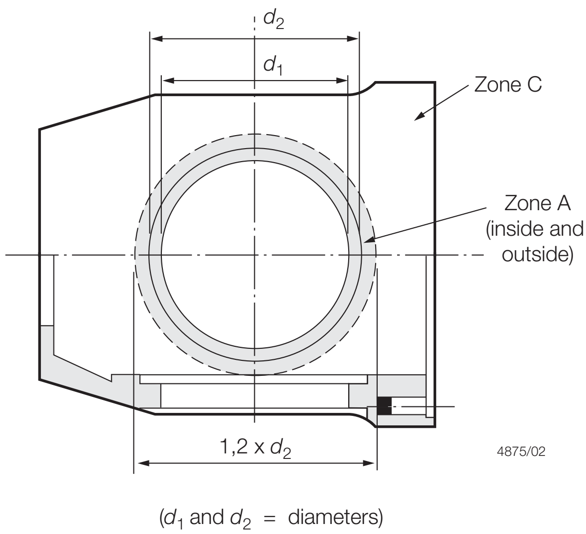


Fig. 9.1.6
Severity zones for controllable pitch propeller hub

1.8.10 On completion of machining and grinding, the whole surface of each casting is to be subjected to a dye penetrant inspection in accordance with a procedure acceptable to LR.

1.8.11 All dye penetrant inspections on Zone A areas in the finished condition are to be made in the presence of the Surveyor.

1.8.12 Dye penetrant inspections on Zones B and C are to be performed by the manufacturer and may be witnessed at the Surveyor's request.

1.8.13 The surface to be inspected shall be divided into reference areas of 100 cm^2. The indications detected shall, with respect to their size and number, not exceed the values given in Table 9.1.3. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

1.8.14 Indications exceeding the acceptance standard in Table 9.1.3 shall be repaired in accordance with 1.9.

1.8.15 All defects requiring repair by welding in new propeller castings are to be recorded on sketches showing their locations and dimensions. Copies of these sketches are to be presented to the Surveyor prior to repair.

1.8.16 Where repairs have been made either by grinding or welding, the repaired areas are to be subjected to dye penetrant inspection in the presence of the Surveyor, regardless of their location.

1.8.17 Where no welds have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.8.18 Where it is suspected that a casting contains internal defects, radiographic and/or ultrasonic examination may be required by the Surveyor. The acceptance criteria are to be agreed between the manufacturer and LR in accordance with a recognised standard. The standard ASTM E272-99 (Severity Level 2) or equivalent is to be the radiographic acceptance standard for copper alloy castings. Ultrasonic testing of Cu 1 and Cu 2 is not considered in these Rules. For Cu 3 and Cu 4, ultrasonic inspection of defects may be possible and is to comply with the requirements for steel castings.

1.8.19 The measurement of dimensional accuracy is the responsibility of the manufacturer but the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made and to witness such checks.

1.8.20 Static balancing is to be carried out on all propellers in accordance with the approved plan. Dynamic balancing is necessary for propellers running above 500 rpm.

1.9 Rectification of defective castings

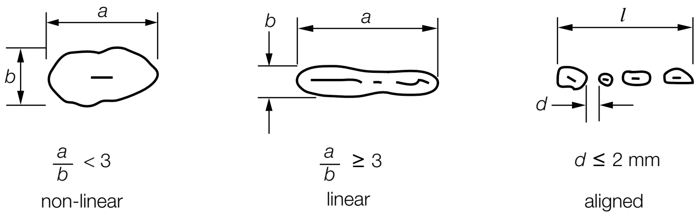
1.9.1 The rectification of defective propeller and propeller blade castings is to be carried out in accordance with the requirements given in 1.9.2 to 1.9.12.

1.9.2 The rectification of small indications within the acceptance standard of Table 9.1.3 is not generally required except where they occur in closely spaced groups.

Table 9.1.3 Allowable number and size of dye penetrant indications in a reference area of 100 cm^2 (*see* Note 1)

Severity Zones	Max. total number of indications	Type of indications (*see* Note 2)	Max. number of each type (*see* Notes 3 and 4)	Max. acceptable value for 'a' or '*l*' of indications (mm) (*see* Note 2)
A	7	Non-linear Linear Aligned	5 2 2	4 3 3
B	14	Non-linear Linear Aligned	10 4 4	6 6 6
C	20	Non-linear Linear Aligned	14 6 6	8 6 6

NOTES
1. The reference area is defined as an area of 0,1 m^2, which may be square or rectangular, with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.
2. Non-linear, linear and aligned indications are defined as follows:



3. Only indications that have any dimension greater than 1,5 mm shall be considered relevant.
4. Single non-linear indications less than 2 mm in Zone A and less than 3 mm in other zones may be disregarded.
5. The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

1.9.3 Where, in the surface of the end face or bore of a propeller boss, local pores are present which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area. The foundry is to maintain records and details of all castings which have been so rectified.

1.9.4 Where unacceptable defects are found in a casting, they are to be removed by mechanical means, and the surfaces of the resulting depressions are subsequently to be ground smooth. Complete elimination of the defects is to be proved by adequate dye penetrant inspection.

1.9.5 Shallow grooves or depressions resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding.

1.9.6 Welded repairs are to be undertaken only when they are considered to be necessary and approved by the Surveyor. In general, welds having an area less than 5 cm^2 are to be avoided.

1.9.7 All weld repairs are to be carried out in accordance with qualified procedures by suitably qualified welders, and are to be completed to the satisfaction of the Surveyor. Records are to be made available to the Surveyor.

1.9.8 Welding is generally not permitted in Zone A and will only be allowed after special consideration.

1.9.9 Prior approval by the Surveyor is required for any welds in Zone B. Complete details of the repair procedure are to be submitted for each case.

1.9.10 Repair by welding is allowed in Zone C provided that there is compliance with 1.9.6 and 1.9.7.

1.9.11 The maximum area of any single repair and the maximum total area of repair in any one zone or region are given in Table 9.1.4.

1.9.12 Where it is proposed to exceed the areas given in Table 9.1.4, the nature and extent of the repair work are to be approved by the Surveyor before commencement of the repair.

1.10 Weld repair procedure

1.10.1 Welding is to be carried out under cover in positions free from draughts and adverse weather conditions.

1.10.2 The manufacturer is to submit a detailed welding procedure specification covering the weld preparation, welding parameters, filler metal, preheating, post-weld heat treatment and inspection procedures.

1.10.3 Before welding is started, Welding Procedure Qualification tests are to be carried out and witnessed by the Surveyor. Each welder is to be qualified to carry out the proposed welding using the same process, consumable and position which are to be used for the repair.

Table 9.1.4 Permissible rectification of new propellers by welding

Severity zone or region	Maximum individual area of repair	Maximum total area of repairs
Zone A	Weld repairs not generally permitted	
Zone B	Defects that are not deeper than (t/40) mm or 2 mm, whichever is greater, below the minimum local thickness are to be removed by grinding. Defects which are deeper than allowable for removal by grinding may be repaired by welding.	
Zone C	60 cm^2 or 0,6% x S whichever is the greater	200 cm^2 or 2% x S, whichever is the greater in combined Zones B and C but not more than 100 cm^2 or 0,8% x S, whichever is the greater, in Zone B on the pressure side
Other regions (*see* Note)	17 cm^2 or 1,5% area of the region whichever is the greater	50 cm^2 or 5% x area of the region whichever is the greater

where t = minimum local thickness in mm

$$S = \text{area of one side of a blade} = 0{,}79 \ \frac{D^2 B}{N}$$

D = finished diameter of propeller
B = developed area ratio
N = number of blades

NOTE
Other regions include:
(a) the bore;
(b) the forward and aft faces of the boss;
(c) the outer surface of the boss to the start of the blade root fillets;
(d) the inner face of a CPP blade palm;
(e) all surfaces of CPP nose cones;
(f) the surfaces of integral journals to CPP blades other than the fillets.

1.10.4 Defects to be repaired by welding are to be removed completely by mechanical means (e.g. grinding, chipping or milling). Removal of defects in accordance with the requirements for Zone A is to be demonstrated by dye penetrant inspection in the presence of the Surveyor. The excavation is to be prepared in a manner which will allow good fusion and is to be clean and dry.

1.10.5 Metal arc welding with the electrodes or filler wire used in the procedure tests is to be used for all types of repairs. Welds should preferably be made in the downhand (flat) position. Where necessary, suitable preheat is to be applied before welding, and the preheat temperature is to be maintained until welding is completed.

1.10.6 When flux coated electrodes are used they are to be dried immediately before use, in accordance with the manufacturer's instructions.

1.10.7 All slag, undercuts and other defects are to be removed before the subsequent run is deposited.

1.10.8 With the exception given in 1.10.9, all weld repairs in areas of solid propellers exposed to sea-water, and all repairs to separately cast blades, are to be stress relief heat treated.

1.10.9 Stress relief heat treatment is not mandatory after welding Grade Cu 3 castings in Zone C unless a welding consumable susceptible to stress corrosion (e.g. complying with the composition range of Grade Cu 4) is used. All welds in Zones A and B however, must be stress relieved by heat treatment, regardless of alloy.

1.10.10 Propeller and propeller blades are to be stress relieved within the following temperature ranges:

alloy Grades Cu 1 and Cu 2	350°C to 550°C
alloy Grade Cu 3	450°C to 500°C
alloy Grade Cu 4	450°C to 600°C

Soaking times are to be in accordance with Table 9.1.5, and subsequent cooling from the soaking temperature is to be suitably controlled to minimise residual stresses and is not to exceed 50°C per hour until the temperature is below 200°C. Care should be taken to avoid heating castings in the Grade Cu 3 alloy at temperatures between 300° and 400°C for prolonged periods.

Table 9.1.5 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature °C (*see* Notes)	Alloy Grade Cu1 and Cu2		Alloy Grade Cu3 and Cu4	
	Hours per 25 mm of thickness	Maximum recommended total time hours	Hours per 25 mm of thickness	Maximum recommended total time hours
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	—	—	1/4	1

NOTES
1. Treatment at 550°C is not applicable to alloy Grade Cu3.
2. Treatment at 600°C is only applicable to alloy Grade Cu4.

1.10.11 Stress relief heat treatment is to be carried out, where possible, in furnaces having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the casting to measure the temperature at positions of extremes of thickness.

1.10.12 As an alternative to 1.10.11, local stress relief heat treatment may be accepted, provided that the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate. Care should be taken to select the shape of an area to be heat treated which will minimise residual stresses.

1.10.13 On completion, welds are to be ground smooth for visual examination and dye penetrant inspection. Where a propeller or propeller blade is to be stress relief heat treated, a visual examination is to be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment. Irrespective of location, all weld repairs are to be assessed according to Zone A in Table 9.1.3.

1.10.14 The foundry is to maintain full records detailing the weld procedure, heat treatment and extent and location on drawings of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10.15 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

1.11 Identification

1.11.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:
(a) Identification mark which will enable the full history of the item to be traced.
(b) Alloy grade.
(c) LR or Lloyd's Register and the abbreviated name of LR local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) Date of final inspection.
(f) Skew angle, if in excess of 25°. *See* Pt 5, Ch 7,1 of the Rules for Ships for the definition of skew angle.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued for each propeller, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting:
(a) Purchaser's name and order number.
(b) Description of casting.
(c) Alloy designation and/or trade name.
(d) Identification number of casting.
(e) Cast identification number if different from (d).
(f) Details of heat treatment, where applicable.
(g) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.
(h) Final weight of casting.
(j) Results of non-destructive tests and details of test procedures.
(k) Proportion of alpha-structure for Cu1 and Cu2 alloys.
(l) Results of mechanical tests.
(m) A sketch showing the location and extent of welding repairs (if any).

Section 2
Castings for valves, liners and bushes

2.1 Scope

2.1.1 This Section makes provision for copper alloy castings for valves, liners, bushes and other fittings intended for use in the construction of ships, other marine structures, machinery and pressure piping systems.

2.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2, and also with the requirements given in this Section.

2.1.3 As an alternative to 2.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

2.2 Manufacture

2.2.1 Castings are to be manufactured at foundries approved by LR.

2.3 Quality of castings

2.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

2.4 Chemical composition

2.4.1 The chemical composition is to comply with the requirements of a National or International Standard and, where appropriate, with the limits for the principal elements of the preferred alloys listed in Tables 9.2.1 and 9.2.2.

2.4.2 With the exception given in 2.4.3, chemical analysis is required on each cast.

2.4.3 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional check tests as requested by the Surveyor. The frequency of these check tests should, as a minimum, be one in every ten casts. If one of these check analyses fails to comply with the specification, checks are to be made on the previous and subsequent melts. If one or both of these further analyses is unsatisfactory, chemical analysis is to be carried out on all further melts until the Surveyor is satisfied that a return can be made to the use of occasional check tests.

2.5 Heat treatment

2.5.1 Where required by the specification, castings may be supplied in either the 'as-cast' or heat treated condition.

2.5.2 Where castings are supplied in a heat treated condition, the test samples are to be heat treated with the castings they represent prior to the preparation of the tensile test specimens.

2.6 Test material

2.6.1 Test material sufficient for the tests specified in 2.6.4 and for possible re-test purposes is to be provided for each cast of material.

2.6.2 The test material is to be separately cast into moulds made of the same material as that used for the castings they represent.

2.6.3 For the alloys listed in Table 9.2.1, sand cast test bars are generally to be in accordance with Fig. 9.2.1.

2.6.4 For the alloys listed in Table 9.2.2, keel block type test samples are to be in accordance with Fig. 9.1.1.

Table 9.2.1 Chemical compositions of long freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition						Typical applications
		Cu	Sn	Zn	Pb	Ni	P	
Phosphor bronze	Cu Sn11P Cu Sn12	87,0 – 89,5 85,0 – 88,5	10,0 – 11,5 11,0 – 13,0	0,05 max. 0,50 max.	0,25 max. 0,7 max.	0,10 max. 2,0 max.	0,5 – 1,0 0,60 max.	Liners, bushes, valves and fittings
Gunmetal	Cu Sn10 Zn2	Remainder	9,5 – 10,5	1,75 – 2,75	1,5 max.	1,0 max.	—	Liners, valves and fittings
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	83,0 – 87,0 85,0 – 89,0 81,0 – 85,0 86,0 – 90,0	4,0 – 6,0 6,0 – 8,0 6,0 – 8,0 5,5 – 6,5	4,0 – 6,0 1,5 – 3,0 2,0 – 5,0 3,0 – 5,0	4,0 – 6,0 2,5 – 3,5 5,0 – 8,0 1,0 – 2,0	2,0 max. 2,0 max. 2,0 max. 1,0 max.	0,10 max. 0,10 max. 0,10 max. 0,05 max.	Bushes, valves and fittings
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	78,0 – 82,0 80,0 – 87,0 74,0 – 80,0 70,0 – 78,0	9,0 – 11,0 4,0 – 6,0 6,0 – 8,0 4,0– 6,0	2,0 max. 2,0 max. 2,0 max. 2,0 max.	8,0 – 11,0 8,0 – 10,0 13,0 – 17,0 18,0 – 23,0	2,0 max. 2,0 max. 0,5 – 2,0 0,5 – 2,5	0,10 max. 0,10 max. 0,10 max. 0,10 max.	Bushes

Table 9.2.2 Chemical compositions of short freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition								Typical applications
		Cu	Ni	Fe	Mn	Cr	Nb	Si	Al	
Copper 30% nickel	Cu Ni30 Fe1 Mn1	64,5 min.	29,0–31,0	0,5–1,5	0,6–1,2	–	–	0,1 max.	–	Flanges, valves and fittings
	Cu Ni30 Fe1 Mn1 Nb Si	Remainder	29,0–31,0	0,5–1,5	0,6–1,2	–	0,5–1,0	0,3–0,7	–	
	Cu Ni30 Cr2 Fe Mn Si (*see* Note 1)	Remainder	29,0–32,0	0,5–1,0	0,5–1,0	1,5–2,0	–	0,15–0,50	–	
Copper 10% nickel	Cu Ni10 Fe1 Mn1	84,5 min.	9,0–11,0	1,0–1,8	1,0–1,5	–	1,0 max.	0,10 max.	–	Flanges, valves and fittings
Aluminium bronze	Cu Al10 Fe5 Ni5	76,0–83,0	4,0–6,0 (*see* Note 2)	4,0–5,5 (*see* Note 2)	3,0 max.	–	–	0,1 max.	8,5–10,5	Bushes, valves and fittings
	Cu Al11 Fe6 Ni6	72,0–78,0	4,0–7,5 (*see* Note 2)	4,0–7,0 (*see* Note 2)	2,5 max.	–	–	0,1 max.	10,0–12,0	

NOTES
1. Normally alloy Cu Ni30 Cr2 Fe Mn Si contains 0,1 to 0,25% titanium and 0,05 to 0,15% zirconium.
2. For Naval ships, the nickel content is to be higher than the iron content.

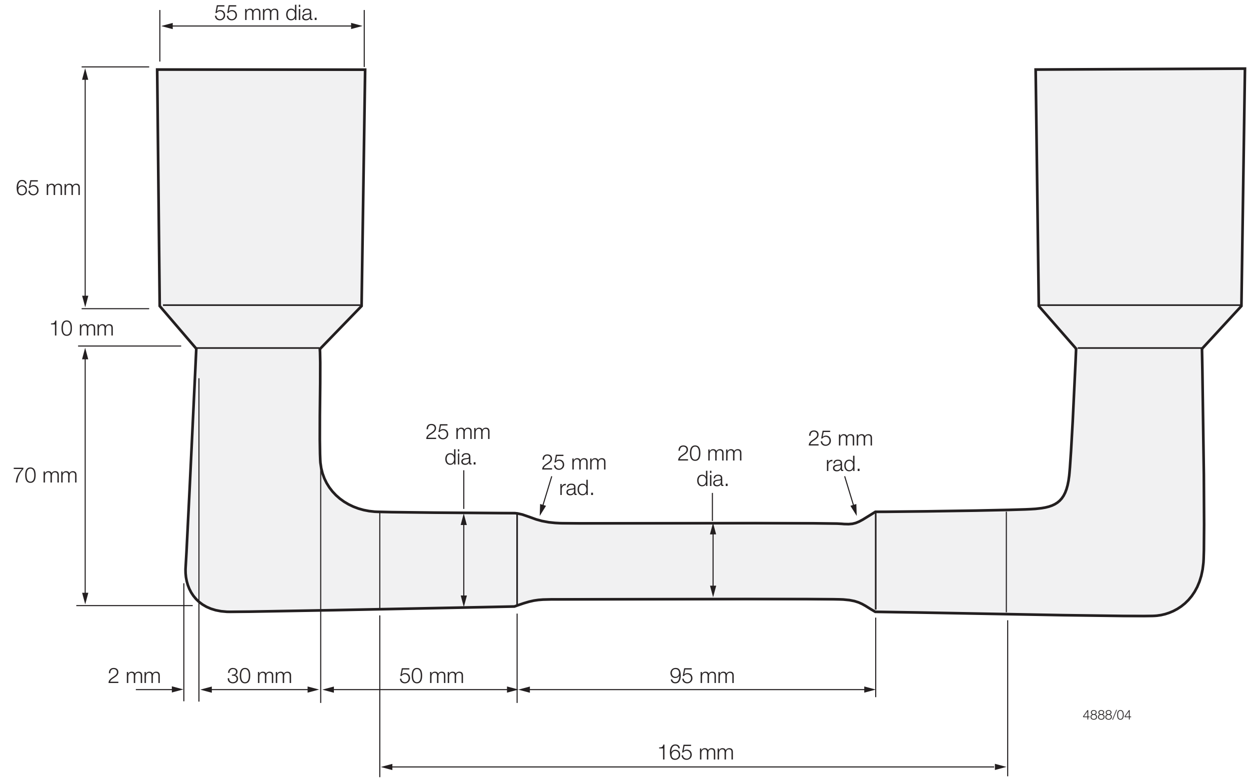


Fig. 9.2.1 Sand cast test bars for long freezing range alloys

2.6.5 If it is proposed to use any other form of test bar, this is to be agreed in advance with the Surveyor.

2.6.6 As an alternative, for liners and bushes, the test material may be taken from the ends of the castings.

2.7 Mechanical tests

2.7.1 A tensile test specimen is to be prepared from each test sample. The dimensions of the specimens are to comply with Fig. 2.2.1 or Fig. 2.2.2 in Chapter 2.

2.7.2 The results of all tests are to comply with the appropriate requirements given in Tables 9.2.3 and 9.2.4.

Table 9.2.3 Mechanical properties of long freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Phosphor bronze	Cu Sn11 P Cu Sn12	130 140	170 150	250 260	330 280	5 7	4 5
Gunmetal	Cu Sn10 Zn2	130	130	270	250	13	5
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	90 130 120 110	110 130 120 110	200 230 230 220	250 260 260 240	13 14 15 15	13 12 12 12
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	80 60 80 70	110 90 90 80	180 160 170 150	220 200 200 170	8 7 8 5	6 6 7 6

NOTES
1. The 0,2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.
2. Castings may be supplied in the chill cast condition in which case the mechanical properties requirements are to be in accordance with a specification agreed by LR.

Table 9.2.4 Mechanical properties of short freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Copper 30% Nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si	120 230 250	120 — —	340 440 440	340 — —	18 18 18	18 — —
Copper 10% Nickel	Cu Ni10 Fe1 Mn1	120	100	280	280	20	25
Aluminium Bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	250 320	280 380	600 680	650 750	13 5	13 5

2.8 Inspection

2.8.1 All castings are to be cleaned and adequately prepared for inspection. Before acceptance, all castings are to be presented to the Surveyor for visual examination. This is to include the examination of internal surfaces, where applicable.

2.8.2 For valves and other pressure components, dye penetrant inspection is required and the Surveyor is to witness the tests. Unless otherwise agreed, the acceptance criteria to be applied are to meet the requirements of Table 9.2.5, or equivalent.

2.8.3 The accuracy and verification of dimensions are the responsibility of the manufacturer. However, the report on dimensional inspection is to be presented to the Surveyor who may request to witness confirmatory measurements.

Table 9.2.5 Visual and surface NDE acceptance criteria for valves and pressure components

Defect type	Acceptance criteria for visual and surface NDE, *see* Note
Linear indications	Not permitted
Porosity	Individual pores are not to exceed 3 mm diameter bleed out, and the sum of the diameters of all indications in an area of 70 x 70 mm is not to exceed 24 mm^2

NOTE
Inspection is to be in accordance with a procedure acceptable to LR.

2.9 Rectification of defective castings

2.9.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

2.9.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to be satisfied that the number, position and size of the defects are such that the castings can be efficiently repaired.

2.9.3 Where approval is given for the repair by welding, complete elimination of the defects is to be proven by adequate non-destructive testing.

2.9.4 All welding is to be in accordance with an approved and qualified weld procedure and carried out by a qualified welder.

2.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as a permanent record. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

2.9.6 The alloys listed in Table 9.2.1 are not satisfactory for repair by welding which is generally not permitted. Weld repairs may, however, be considered in special circumstances provided that a suitable procedure, with proof of previous satisfactory repairs is submitted to the Surveyor.

2.9.7 The welding during manufacture of liners is not permitted in any alloy containing more than 0,5 per cent lead.

2.10 Pressure testing

2.10.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

2.11 Identification

2.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the casting when required.

2.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:
(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

2.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

2.12 Certification of materials

2.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

2.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and alloy grade.
(c) Identification number.
(d) Ingot or cast analysis.
(e) Full details of heat treatment, where applicable.
(f) Mechanical test results.
(g) Test pressure, where applicable.

2.12.3 In addition to 2.12.2, the manufacturer is to provide, where applicable, a statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

■ *Section 3* Tubes

3.1 Scope

3.1.1 Provision is made in this Section for seamless copper and copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

3.1.2 Tubes for Class I and II pressure systems (as defined in the relevant Rules) are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2 and the requirements of this Section.

3.1.3 As an alternative to 3.1.2, tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.1.4 Tubes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of a National or International Standard recognised by LR. The manufacturer's test certificate will be acceptable and is to be provided for each batch of material.

3.2 Manufacture

3.2.1 Tubes for Class I and II pressure systems are to be manufactured at a works approved by LR for the grade of material being supplied.

3.2.2 Tubes for Class III pressure systems are not required to be manufactured at a works approved by LR.

3.3 Quality

3.3.1 Tubes are to be clean and free from surface and internal defects and residues from manufacturing operations.

3.3.2 The tubes are to be supplied in smooth, round, straight lengths and the manufacturer is to guarantee freedom from deleterious films in the bore. The ends are to be cut clean and square with the axis of the tube and are to be de-burred.

3.4 Dimensional tolerances

3.4.1 The tolerances on the wall thickness and diameter of the tubes are to be in accordance with a National or International Standard recognised by LR.

3.4.2 The measurement of dimensional accuracy and compliance with the specification are the responsibility of the manufacturer, but the reports are to be made available to the LR Surveyors, who may require checks to be made in their presence.

3.5 Chemical composition

3.5.1 The chemical composition is to comply with the requirements of a National or International Standard recognised by LR and comply with the base limits for the principal elements given in Table 9.3.1.

3.6 Heat treatment

3.6.1 Copper-phosphorus and aluminium brass tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

3.6.2 Tubes in the copper-nickel iron alloys are to be supplied in a solution heat treated condition to ensure that no iron rich phases are present.

3.7 Mechanical tests

3.7.1 Tubes are to be presented for test in batches of 300 lengths. A batch is to consist of tubes of the same size, manufactured from the same material grade.

3.7.2 At least one length is to be selected at random from each batch and subjected to the following tests:
(a) Tensile test.
(b) Flattening test.
(c) Drift expanding test.

3.7.3 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

3.7.4 The flattening test is to be continued until the interior surfaces of the tube meet.

3.7.5 For the drift expanding test, the mandrel is to have an included angle of 45°.

3.7.6 The results of all mechanical tests are to comply with the appropriate requirements given in Table 9.3.2.

3.7.7 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

Table 9.3.1 Chemical composition of principal elements only

Designation	Chemical composition %								
	Cu	As	P	Fe	Pb	Ni	Al	Mn	Zn
Copper-phosphorus deoxidised–non-arsenical	99,85 min.	–	0,013–0,050	—	—	—	—	—	—
Copper-phosphorus deoxidised–arsenical	99,2 min.	0,30–0,50	0,013–0,050		—	—	—	—	—
Aluminium brass	76,0–79,0	0,02–0,06	—	0,06 max.	0,07 max.	—	1,8–2,5	—	Remainder
90/10 Copper-nickel-iron (*see* Note)	Remainder	—	—	1,0-2,0	—	9,0–11,0	—	0,5–1,0	—
70/30 Copper-nickel-iron (*see* Note)	Remainder	—	—	0,40–1,00	—	29,0–33,0	—	0,5–1,5	—

NOTE
Where the purchaser specifies that the product is intended for subsequent welding applications, the following limits will apply:

Zn	0,50% max.	S	0,02% max.
Pb	0,02% max.	C	0,05% max.
P	0,02% max.		

Table 9.3.2 Mechanical properties for acceptance purposes

Designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Drift expansion test % minimum	Grain size mm maximum (*see* Note)
Copper-phosphorus deoxidised–non-arsenical	65	220	40	40	—
Copper-phosphorus deoxidised–arsenical	65	220	40	40	—
Aluminium brass	125	320	40	30	0,045
90/10 Copper-nickel-iron	100	270	30	30	0,045
70/30 Copper-nickel-iron	120	360	30	30	0,045

NOTE
When a maximum grain size is specified, the structure is to be completely re-crystallised. The manufacturer is to guarantee the grain size, but testing of each batch will not be required.

3.8 Visual examination

3.8.1 All tubes are to be visually examined. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

3.8.2 The inner and outer surfaces are to be clean and smooth but may have a superficial, dull iridescent film on both the inner and outer surfaces.

3.9 Hydraulic test

3.9.1 Each tube is to be subjected to a hydraulic test at the manufacturer's works.

3.9.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 70 bar:

$$P = \frac{20st}{D}$$

where
P = test pressure, in bar
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 40 for copper-phosphorus
60 for Al-brass and
90/10 copper nickel iron
75 for 70/30 copper nickel iron.

3.9.3 The test pressure is to be maintained for sufficient time to permit proof that the tubes do not weep, leak or undergo a permanent increase in diameter. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

3.9.4 Where it is proposed to adopt a test pressure other than that determined in 3.10.2, the proposal will be subject to special consideration.

3.9.5 Subject to special approval, an automated eddy current test can be accepted in lieu of the hydraulic test. Discontinuous irregularities on the external and internal surfaces of the tubes are permitted if they are within the agreed dimensional tolerances, with the exception of cracks, which are not permitted.

3.10 Rectification of defects

3.10.1 The repair of defects by welding is not permitted.

3.11 Identification

3.11.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:
(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Grade of material or designation code.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

3.11.2 Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

3.12 Certification of materials

3.12.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1), giving the following particulars for each casting or batch of castings which has been accepted:
(a) Purchaser's name and order number.
(b) Specification or grade of material.
(c) Description and dimensions.
(d) Cast number and chemical composition.
(e) Mechanical test results.
(f) Results of stress corrosion cracking test, where applicable.
(g) Hydraulic test report.

Section

■ *Section 1* Anchors

1.1 Scope

1.1.1 This Section makes provision for the manufacture and testing of anchors constructed from cast, forged and fabricated components.

1.1.2 This Section is applicable to the following types of anchor:
(a) Ordinary.
(b) High holding power (HHP).
(c) Super high holding power (SHHP).

1.1.3 In the context of this Section, the reference to swivels refers to those directly attached to the anchor shank in lieu of the conventional ‘D’ shackle. For other mooring equipment swivels, *see* 2.13.

1.2 Manufacture

1.2.1 All anchors are to be of an approved design.

1.3 Cast steel anchors

1.3.1 Cast steel anchor heads, shanks, shackles and swivels are to be manufactured and tested in accordance with the requirements of Ch 4,1 and Ch 4,2. The Special grade quality is to be used for anchor heads, shanks and shackles.

1.3.2 Special consideration will be given to the use of other grades of steel for the manufacture of swivels.

1.3.3 To confirm the quality of cast anchor components, the Surveyor is to witness drop and hammering tests.

1.3.4 When drop and hammering tests are required, they are to be carried out as follows:
(a) Each anchor, or the components of an anchor made from more than one piece, is to be dropped from a clear height of 4 m onto a steel slab laid on a solid foundation.
(b) Separately cast flukes, shanks and shackles are to be suspended horizontally from a clear height of 4 m before being dropped.
(c) Anchors cast in one piece are to be drop tested twice from a clear height of 4 m. For the first test, the shank and flukes are to be horizontal. For the second test, two steel blocks are to be placed on the slab, arranged so that the middle of each fluke makes contact with the blocks without the crown making contact with the slab, and the orientation of the anchor is to be vertical with the crown nearest the slab.
(d) If the slab is broken by the impact, the test is to be repeated on a new slab.

1.3.5 When hammering tests are required, they are to be carried out after the drop test on each anchor head and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

1.3.6 As part of the manufacturer’s works approval, consideration may be given to carrying out drop tests in alternative locations to the manufacturer’s when the facilities and location are not suitable.

1.3.7 Repair of fractures or unsoundness detected during the drop or hammering tests are not permitted and the component is to be rejected.

1.4 Forged steel anchors

1.4.1 Forged steel anchor pins, swivels, shanks and shackles are to be manufactured and tested in accordance with the requirements of Ch 5,1 and Ch 5,2 carbon and carbon-manganese steel for welded construction. Rolled steel bar may be used provided that the requirements of Ch 5,1.2.9 are met.

1.4.2 Special consideration will be given to other grades of steel for the manufacture of swivels.

1.5 Fabricated steel anchors

1.5.1 Where it is proposed to use plate material for fabricated steel anchors, it is to comply with the requirements of Ch 3,2 or Ch 3,3, and the proposed manufacturing procedure is to be submitted for approval.

1.5.2 Fabricated anchors are to be manufactured in accordance with Chapter 13.

1.5.3 Stress relief is to be carried out as required in the approved welding procedure.

1.6 Rectification

1.6.1 All rectification is to be agreed with the Surveyor.

1.6.2 Rectification of defective castings is to be carried out in accordance with Ch 4,1.9.

1.6.3 Rectification of defective forgings is to be carried out in accordance with Ch 5,1.9.

1.6.4 Rectification of defective fabricated anchors is to be carried out by suitably qualified welders within the parameters of the approved welding procedure used in construction.

1.6.5 Rectification of defective castings, forgings or fabricated anchors by welding is to be carried out using qualified weld procedures in accordance with Ch 12,1 and Ch 12,2, and in accordance with Ch 13,1 and Ch 13,2.

1.7 Super high holding power (SHHP) anchors

1.7.1 The impact test requirements for SHHP anchor shackles are to be in accordance with the requirements for Grade U3 in Table 10.2.1.

1.8 Assembly

1.8.1 Assembly and fitting is to be carried out in accordance with the approved design.

1.8.2 Securing of anchor pins, shackle pins or swivels by welding is to be carried out by suitably qualified welders in accordance with an approved welding procedure.

1.9 Proof test of anchors

1.9.1 Anchors having a mass of 75 kg or more inclusive of stock (56 kg in the case of high holding power anchors) are to be tested in the presence of the Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

1.9.2 The anchor is to be visually examined before application of the proof test load to ensure that it is free from cracks, notches, inclusions and other surface defects that would impair the performance of the product.

1.9.3 As required by 1.9.1, each anchor is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.1.1 for the appropriate mass of the anchor. The proof load is to be applied on the arm or on the palm at a spot which, measured from the extremity of the bill, is one-third of the distance between it and the centre of the crown. For stocked anchors, each arm is to be tested individually. For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

Table 10.1.1 Proof load tests for anchors
(*see* Notes 1 and 2)

Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN
50	23,2	2200	376,0	7800	861,0
55	25,2	2300	388,0	8000	877,0
60	27,1	2400	401,0	8200	892,0
65	28,9	2500	414,0	8400	908,0
70	30,7	2600	427,0	8600	922,0
75	32,4	2700	438,0	8800	936,0
80	33,9	2800	450,0	9000	949,0
90	36,3	2900	462,0	9200	961,0
100	39,1	3000	474,0	9400	975,0
120	44,3	3100	484,0	9600	987,0
140	49,0	3200	495,0	9800	998,0
160	53,3	3300	506,0	10 000	1010,0
180	57,4	3400	517,0	10 500	1040,0
200	61,3	3500	528,0	11 000	1070,0
225	65,8	3600	537,0	11 500	1090,0
250	70,4	3700	547,0	12 000	1110,0
275	74,9	3800	557,0	12 500	1130,0
300	79,5	3900	567,0	13 000	1160,0
325	84,1	4000	577,0	13 500	1180,0
350	88,8	4100	586,0	14 000	1210,0
375	93,4	4200	595,0	14 500	1230,0
400	97,9	4300	604,0	15 000	1260,0
425	103,0	4400	613,0	15 500	1280,0
450	107,0	4500	622,0	16 000	1300,0
475	112,0	4600	631,0	16 500	1330,0
500	116,0	4700	638,0	17 000	1360,0
550	125,0	4800	645,0	17 500	1390,0
600	132,0	4900	653,0	18 000	1410,0
650	140,0	5000	661,0	18 500	1440,0
700	149,0	5100	669,0	19 000	1470,0
750	158,0	5200	677,0	19 500	1490,0
800	166,0	5300	685,0	20 000	1520,0
850	175,0	5400	691,0	21 000	1570,0
900	182,0	5500	699,0	22 000	1620,0
950	191,0	5600	706,0	23 000	1670,0
1000	199,0	5700	713,0	24 000	1720,0
1050	208,0	5800	721,0	25 000	1770,0
1100	216,0	5900	728,0	26 000	1800,0
1150	224,0	6000	735,0	27 000	1850,0
1200	231,0	6100	740,0	28 000	1900,0
1250	239,0	6200	747,0	29 000	1940,0
1300	247,0	6300	754,0	30 000	1990,0
1350	255,0	6400	760,0	31 000	2030,0
1400	262,0	6500	767,0	32 000	2070,0
1450	270,0	6600	773,0	34 000	2160,0
1500	278,0	6700	779,0	36 000	2250,0
1600	292,0	6800	786,0	38 000	2330,0
1700	307,0	6900	794,0	40 000	2410,0
1800	321,0	7000	804,0	42 000	2490,0
1900	335,0	7200	818,0	44 000	2570,0
2000	349,0	7400	832,0	46 000	2650,0
2100	362,0	7600	845,0	48 000	2730,0

Proof loads for intermediate mass are to be determined by linear interpolation

NOTES

1. Where ordinary anchors have a mass exceeding 48 000 kg, the proof loads are to be taken as 2,059 (mass of anchor in kg)$^{2/3}$ kN.
2. Where high holding power anchors have a mass exceeding 36 000 kg, the proof loads are to be taken as 2,452 (actual mass of anchor in kg)$^{2/3}$ kN.

1.9.4 The general arrangements for the test are to be such that the complete anchor, including the shackle, shackle pins and any welded or bolted connections are included in the test. If a replacement shackle is needed which requires welding or heating for fitting, the combined anchor and shackle are to be proof load tested. If welding or heating is not involved in fitting, the shackle may be proof load tested separately from the anchor.

1.9.5 The mass to be used in Table 10.1.1 is:

(a) For stockless anchors, the total mass of the anchor.
(b) For stocked anchors, the mass of the anchor excluding the stock.
(c) For high holding power anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor.
(d) For mooring anchors, including positional mooring anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor, unless specifically agreed otherwise.
(e) For super high holding power anchors, a nominal mass equal to twice the actual total mass of the anchor.

1.9.6 For positional mooring anchors, the proof test loading is to be that required by 1.9.3 or 50 per cent of the minimum break strength of the intended anchor line, whichever is the greater.

1.9.7 The gauge length is to be measured with 10 per cent of the required load applied, before and after proof test. The two measurements shall differ by no more than 1 per cent. The gauge length is the distance between the tip of each fluke and a point on the shank adjacent to the shackle pin, *see* Fig. 10.1.1.

1.9.8 After proof testing, all accessible surfaces are to be visually inspected by the Surveyor.

1.9.9 Following proof testing, NDE is to be conducted as described in Table 10.1.2 for ordinary and HHP anchors and Table 10.1.3 for SHHP anchors.

1.9.10 Each casting is to be subjected to ultrasonic inspection in the region of runners and risers, or where excess material has been removed by thermal methods. This examination is to extend around the whole periphery of the casting and for a distance of $t/3$ beyond the area affected, where t is the maximum thickness. In addition, random areas are to be selected by the Surveyor and examined.

1.9.11 Acceptance criteria for castings are to be in accordance with Chapter 4.

1.9.12 Acceptance criteria for forgings are to be in accordance with Chapter 5.

1.9.13 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.1.2 NDE requirements following proof testing for Ordinary and HHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Penetrant testing is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

Table 10.1.3 NDE requirements following proof testing for SHHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All surfaces of castings	Magnetic particle inspection
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Additionally, all surfaces of all SHHP anchors are to be surface inspected by the magnetic particle or penetrant method as appropriate.
3. Penetrant is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

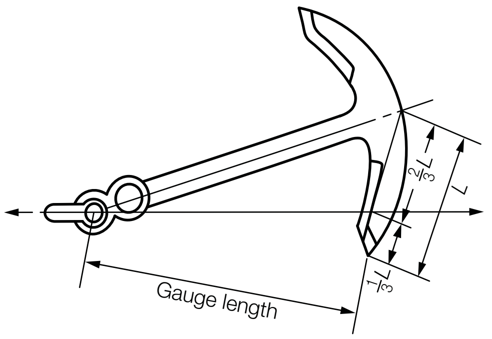


Fig. 10.1.1 Location of gauge length measurement during proof load

1.9.14 On completion of the proof testing, anchors made in more than one piece are to be examined for free movement of their heads over the complete range of rotation.

1.10 Clearances and tolerances

1.10.1 Where no fitting tolerances are specified on the approved plans the following assembly and fitting tolerance are to be applied.

1.10.2 The clearance either side of the shank within the shackle jaws and the shackle pin in the shank end hole is to be no more than 3 mm for small anchors up to 3 tonnes, 4 mm for anchors up to 5 tonnes, 6 mm for anchors up to 7 tonnes and is not to exceed 12 mm for larger anchors.

1.10.3 The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter and the eyes of the shackle are to be chamfered on the outside to ensure a good tightness when the pin is fitted. The shackle pin is to mate with the shackle such that it can be inserted with moderate hand pressure, allowing disassembly if required.

1.10.4 The trunnion pin is to fit within the chamber such that it will achieve the closest fit which can be carried out by hand. The pin is to be long enough to prevent horizontal movement. The gap is to be no more than 1 per cent of the chamber length.

1.10.5 The lateral movement of the shank is not to exceed 3 degrees from the centreline datum, *see* Fig. 10.1.2.

1.10.6 Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is in lieu of the conventional 'D' shackle.

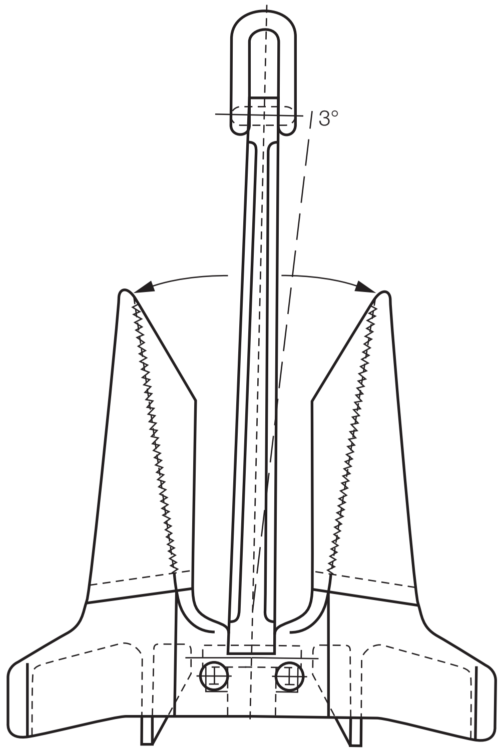


Fig. 10.1.2 Allowable lateral movement of shank

1.11 Identification

1.11.1 Identification marks on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the centre line of the crown on the right hand fluke, looking from the crown towards the shank.

1.11.2 The following details are to be shown on all anchors:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of the certificate.
(c) Month and year of test.

(d) Mass (also the letters 'HHP' when approved as high holding power anchors or 'SHHP' when approved as super high holding power anchors).
(e) Mass of stock (in the case of stocked anchors).
(f) National Authority requirements, as applicable.
(g) Manufacturer's mark.

1.11.3 In addition to 1.11.2, each important part of an anchor is to be plainly marked by the maker with the words 'forged steel' or 'cast steel' as appropriate. Fabricated steel anchor heads do not require special marking.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement that the anchor has been manufactured and tested in accordance with LR Rules together with the following particulars:
(a) Purchaser's name and order number.
(b) Type of anchor and principal dimensions.
(c) Mass of anchor.
(d) Identification mark which will enable the full history of manufacture to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Proof load.
(j) Results of the non-destructive examination.
(k) Weld location maps (cast steel anchors only).

1.12.2 Shanks, heads, pins, shackles and swivels are to be certified by LR in accordance with the relevant sections of Chapters 3, 4 and 5.

1.12.3 An LR Anchor Certificate is to be issued for the completed anchor which will include the following particulars:
(a) Manufacturer's name.
(b) Type of anchor.
(c) Mass of anchor.
(d) Grade of materials.
(e) Proof test load.
(f) Heat treatment.
(g) Marking applied to anchor.
(h) Dimensions.
(j) General Approval of an Anchor Design Certificate Number.
(k) Fluke and shank identification numbers.

■ *Section 2*
Stud link chain cables for ships

2.1 Scope

2.1.1 Provision is made in this Section for a range of grades, U1, U2 and U3, of stud link chain and fittings intended for anchor cables for ships.

2.1.2 The requirements for mooring chain cables are given in Section 3.

2.1.3 The design of chain cables is to be to a Standard recognised by LR, such as ISO 1704.

2.2 Manufacture

2.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers of stud link chain cables and fittings is published separately by LR.

2.2.2 The links may be made by the flash-butt or other approved welding process, or in the case of Grades U2 and U3 they may be flash-butt welded or drop forged, designated U2(a) or U3(a), or cast steel designated U2(b) or U3(b), *see* Table 10.2.5.

2.2.3 As far as practicable, consecutive links in all chain cable should originate from a single cast or batch of bar stock (*see* Ch 3,9.6.1), and indicating marks should be stamped on the final link formed from one cast or batch and the first link formed from a separate cast or batch.

2.2.4 A length of chain cable is to measure not more than 27,5 m and is to comprise an odd number of links. In this context, a length is a statutory term and is the basis for the number of test samples.

2.2.5 Where end links or enlarged links are manufactured and heat treated as part of and at the same time as the chain cable and are of the same cast heat of steel, they may be excluded from separate mechanical tests and break load tests.

2.3 Flash butt welded chain cable

2.3.1 Bar material is to comply with the requirements of Ch 3,9 and may be heated either by electrical resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control. The temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and checks are to be recorded.

2.3.2 Mechanical properties testing of U1 cable is not required. For Grade U2 cable supplied in the as-welded condition, and Grade U3 in all conditions, one tensile and one set of three Charpy V-notch impact test specimens are to be taken at the side of a link opposite the weld from at least every fourth 27,5 m length of cable. A further set of three impact test specimens is to be taken with the notch positioned at the centre of the weld, *see* Table 10.2.3. The test specimens are not to be selected from the same length as that from which the breaking test sample is taken, unless breaking test samples are to be taken from every length of the batch. All test samples are to be correctly identified with the lengths of cable represented.

2.3.3 The test links from which the mechanical test specimens are prepared are to be made as part of the chain cable and are to be heat treated with it. They may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents prior to preparation of the mechanical test specimens.

2.3.4 The results of tests on specimens taken from the non-welded areas are to comply with the appropriate requirements of Table 10.2.1. The results of tests on the welds are to comply with the requirements of Table 10.2.6.

2.4 Cast chain cables

2.4.1 The manufacture of cast steel chain cable is generally to be in accordance with the requirements of Ch 4,1, as appropriate.

2.4.2 The chemical composition of ladle samples is to comply with the specification approved by LR.

2.4.3 Separately cast test samples are to be provided from each cast. They are to be of similar dimensions to the links they represent and are to be heat treated together with, and in the same manner as, the completed chain cable, *see* Table 10.2.3.

2.4.4 Tensile and Charpy V-notch impact test specimens are to be taken from each test sample and machined to the dimensions given in Ch 2,3.

2.4.5 The results of all tests are to comply with the requirements given in Table 10.2.1 for the relevant grade.

2.5 Forged chain cables

2.5.1 The procedure for the manufacture and testing of drop forgings for chain cable will be specially considered, but is generally to be in accordance with the appropriate requirements of Ch 5,1.

2.5.2 The chemical composition is to comply with Table 10.2.2.

2.5.3 The completed forgings are to be heat treated in accordance with Table 10.2.3.

2.5.4 Test samples are to be provided in the form of forgings of similar dimensions to the links they represent. These test samples are to be from the same steel-making heat and heat treated together with the links they represent.

2.5.5 One tensile and three Charpy V-notch specimens are to be taken from each test sample.

Table 10.2.1 Mechanical properties of finished chain cable and fittings

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
U2	295	490 – 690	22	—	0 (*see* Note 1)	27
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35

NOTES
1. When required *see* Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C.
3. Mechanical testing is not required for finished chain cables and fittings in Grade U1.

Table 10.2.2 Chemical composition of butt welded and forged chain cable

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	N max.	Cr max.	Cu max.	Nb max.	Ni max.	V max.	Mo max.
U1	0,20	0,15 – 0,35	0,40 min.	0,04	0,04	—	—	—	—	—	—	—	—
U2	0,24	0,15 – 0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	—	—	—	—	—	—	—
U3	0,33	0,15 – 0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,015	0,25	0,35	0,05 *see* Note 2	0,40	0,10 *see* Note 2	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings

Grade	Manufacturing method	Condition of supply	Number of test specimens on every four lengths of chain cable of 27,5 m or less, or on each batch of fittings		
			Tensile test on base materials	Charpy V-notch impact test	
				Base material	Weldment
U1 cable	Flash butt welded	As welded Normalised	— —	— —	— —
U2 cable	Flash butt welded	As welded Normalised	1 —	3 —	3 —
U3 cable	Flash butt welded	Normalised Normalised and Tempered Quenched and Tempered	1	3	3
U2 cable	Cast or drop forged	Normalised	1	3	—
U3 cable	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—
U2 fittings	Cast or drop forged	Normalised	1	3	—
U3 fittings	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—

2.5.6 The results of mechanical tests are to comply with the requirements of Table 10.2.1 for the relevant grade.

2.6 Stud material

2.6.1 Steel studs are to be used for all grades of welded chain cable. In general, the carbon content should not exceed 0,23 per cent but mechanical tests for acceptance purposes are not required.

2.7 Welding of studs

2.7.1 Where studs are welded into the links this is to be completed before the chain cable is heat treated.

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery. Weld start/stop positions are not to be located in the plane of the chain cable.

2.7.3 The welds are to be made by qualified welders using an approved procedure and consumables approved to Grade 3 and low hydrogen, in accordance with Chapter 11.

2.7.4 The welds are to be of good quality and free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar stress raising defects shall, where necessary, be ground off.

2.7.5 At least one stud weld within each length of cable is to be inspected using dye penetrant testing in accordance with Ch 1,5 after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using dye penetrant.

2.8 Heat treatment of completed chain cables

2.8.1 The completed chain cable is to be heat treated in accordance with Table 10.2.3 for the appropriate grade of cable.

2.8.2 Special consideration will be given to the heat treatment of certain types of drop forged chain cable.

2.8.3 In all cases, heat treatment is to be carried out prior to the proof loading and breaking tests.

2.8.4 All test samples are to be heat treated with, and in the same way as, the chain cables they represent.

2.9 Testing of completed chain cables

2.9.1 All chain cables are to be subjected to a Proof Load test and a Breaking Load test. In addition, mechanical tests should be carried out where required, *see* Table 10.2.3.

2.9.2 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

2.10 Proof load tests

2.10.1 Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable.

2.10.2 On completion of the test, each link is to be visually examined and is to be free from significant defects. Special attention is to be given to welds.

2.10.3 Should any link be found to be defective it is to be replaced by an approved connecting link (joining shackle or substitute link as detailed in 2.14). The chain is then to be subjected to a repeat of the proof load test followed by re-examination.

2.10.4 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 2.12. If either of these samples fails, the length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected.

2.11 Dimensional inspection

2.11.1 The measurement of dimensions in 2.11.2 and 2.11.3 is to take place after the proof load has been applied to the chain and subsequently reduced to the load of 10 per cent of the proof load. All other dimensional checks are to be carried out without application of load.

2.11.2 On every 27,5 m length of chain, five links are to be selected for measurement of length to ensure that the maximum allowable tolerance on a length of five links is plus 2,5 per cent. No under-tolerance is permitted.

2.11.3 If a five-link length of chain exceeds the tolerance given in 2.11.2, then the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links. Oversize links are to be removed and an approved connecting link inserted.

2.11.4 Checks of all other dimensions are to be made on three links from every four 27,5 m lengths. All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

2.11.5 If one of the links detailed in 2.11.4 fails to comply with the required tolerances, measurements are to be made on all four 27,5 m lengths.

2.11.6 If more than one link in a 27,5 m length of chain cable fails to meet the tolerance requirements, all the links in that length are to be measured.

2.11.7 Links that fail to comply with tolerance requirements are to be removed and approved connecting links inserted. Where a significant number of links fail to comply with the tolerance requirements the chain is to be rejected.

2.11.8 The form and proportion of links and shackles are to be in accordance with a standard recognised by LR, such as ISO 1704; alternatively, the design may be specifically approved by LR.

2.11.9 Manufacturing tolerances on stud link chain are to be within ±2,5 per cent (taking into account that all components of the chain are to be a good fit with one another), except for those detailed in 2.11.10.

2.11.10 The nominal diameter, d, is to be the average of the diameters, measured in the plane of the link, d_c, and perpendicular to the plane of the link, d_p, *see* Fig. 10.2.1. The negative tolerance on the nominal diameter is not to exceed the following:

Minus 1 mm when $d \leq 40$ mm
Minus 2 mm when 40 mm $< d \leq 84$ mm
Minus 3 mm when 84 mm $< d \leq 122$ mm
Minus 4 mm when $d > 122$ mm

The plus tolerance on the diameter at the crown measured out of the plane of the link, d_p, is not to exceed 5 per cent.

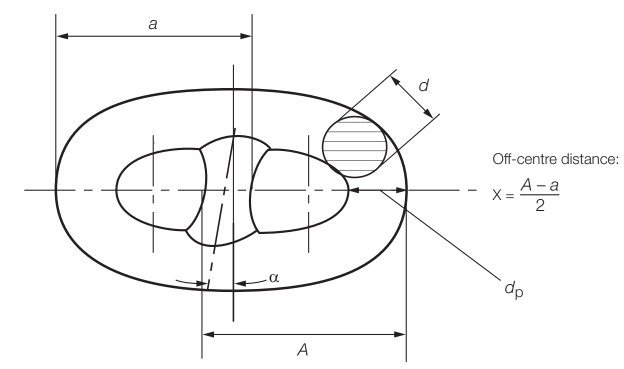


Fig. 10.2.1 Manufacturing tolerances

2.11.11 The cross-sectional area is to be calculated using the nominal diameter, d. The cross-sectional area at the crown of the link is to have no negative tolerance.

2.11.12 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 in Chapter 3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

Table 10.2.4 Test loads for stud link anchor chain cables

Chain diameter	Grade U1		Grade U2		Grade U3	
	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN
d mm	$0,00686d^2 (44-0,08d)$	$0,00981d^2 (44-0,08d)$	$0,00981d^2 (44-0,08d)$	$0,01373d^2 (44-0,08d)$	$0,01373d^2 (44-0,08d)$	$0,01961d^2 (44-0,08d)$
12,5	46	66	66	92	—	—
14	58	82	82	115	—	—
16	75	107	107	150	—	—
17,5	89	128	128	179	—	—
19	105	150	150	211	—	—
20,5	122	175	175	244	244	349
22	140	201	201	281	281	401
24	166	238	238	333	333	475
26	194	278	278	389	389	556
28	225	321	321	450	450	642
30	257	367	367	514	514	734
32	291	416	416	583	583	832
34	327	468	468	655	655	936
36	366	523	523	732	732	1045
38	406	580	580	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	984	984	1406
44	538	769	769	1076	1076	1537
46	585	837	837	1171	1171	1673
48	635	908	908	1270	1270	1814
50	686	981	981	1373	1373	1961
52	739	1057	1057	1479	1479	2113
54	794	1135	1135	1589	1589	2269
56	850	1216	1216	1702	1702	2430
58	908	1299	1299	1818	1818	2597
60	968	1384	1384	1938	1938	2767
62	1029	1472	1472	2060	2060	2943
64	1092	1562	1562	2187	2187	3123
66	1157	1655	1655	2316	2316	3308
68	1223	1749	1749	2448	2448	3496
70	1291	1846	1846	2583	2583	3690
73	1395	1995	1995	2792	2792	3988
76	1503	2149	2149	3007	3007	4295
78	1576	2254	2254	3154	3154	4505
81	1689	2415	2415	3380	3380	4827
84	1805	2580	2580	3612	3612	5158
87	1923	2750	2750	3849	3849	5498
90	2045	2924	2924	4093	4093	5845
92	2127	3042	3042	4258	4258	6081
95	2254	3223	3223	4510	4510	6442
97	2339	3345	3345	4682	4682	6687
100	2470	3532	3532	4943	4943	7060
102	2558	3658	3658	5120	5120	7312
105	2692	3850	3850	5389	5389	7697
107	2783	3980	3980	5571	5571	7957
111	2968	4245	4245	5941	5941	8486
114	3110	4447	4447	6224	6224	8889
117	3253	4652	4652	6511	6511	9299
120	3398	4859	4859	6801	6801	9714
122	3496	4999	4999	6997	6997	9994
124	3595	5141	5141	7195	7195	10276
127	3744	5354	5354	7494	7494	10703
130	3895	5571	5571	7796	7796	11135
132	3997	5716	5716	8000	8000	11426
137	4254	6083	6083	8514	8514	12161
142	4515	6456	6456	9036	9036	12906
147	4779	6834	6834	9565	9565	13662
152	5046	7217	7217	10100	10100	14426
157	5316	7602	7602	10640	10640	15197
162	5588	7991	7991	11185	11185	15975

2.11.13 Studs must be located in the links centrally and at right angles to the sides of the link, although the studs at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances in Fig. 10.2.1 will be accepted provided that the stud fits snugly and its ends lie practically flush against the inside of the link:

Maximum off-centre distance 'X': 10 per cent of the nominal diameter *d*

Maximum deviation 'α' from the 90° – position: 4°.

2.11.14 All individual parts must have a clean surface consistent with the method of manufacture and the surface is to be free from cracks, notches, inclusions and other defects which could impair the performance of the product. Crack-like imperfections less than 3 mm in length can be ignored. The flash produced by upsetting or drop forging must be properly removed.

2.11.15 Minor surface imperfections may be ground off so as to leave a gentle transition to the surrounding surface provided that the cross-sectional area remains equal to or greater than the nominal cross-sectional area. Remote from the crown, local grinding up to 5 per cent of the nominal diameter may be permitted.

2.11.16 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

2.12 Breaking load tests

2.12.1 Breaking load tests are to be carried out on three-link samples selected by the Surveyor from the completed (including heat treatment) chain. The test links may be removed from the chain prior to heat treatment provided that each sample is heat treated with, and in the same manner as the chain it represents. They are to be properly identified with the lengths of chain they represent.

2.12.2 The number of tests required is to be in accordance with Table 10.2.5 except that for chafing chain for Emergency Towing Arrangements (ETA), *see* Pt 3, Ch 13,10.2, one test is to be carried out on each 110 m of finished chains.

2.12.3 Breaking test specimens are to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load for a minimum of 30 seconds.

2.12.4 Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch. If one of these further tests fails, the entire set of lengths represented by the original test is to be rejected.

2.12.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

Table 10.2.5 Number of breaking tests from completed cables

Designation	Method of manufacture	Number of breaking test specimens
Grade U1	Flash-butt welded and heat treated	One from every four lengths of 27,5 m or less
Grade U2(a) U3(a)	Flash-butt welded, or drop forged and heat treated	One from every four lengths of 27,5 m or less
Grade U1 U2(a)	Flash-butt welded but not heat treated	One from each length of 27,5 m or less
Grade U2(b) U3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m or less

Table 10.2.6 Mechanical properties of welds in chain cables

Grade	Charpy V-notch impact test	
	Test temperature °C	Average energy J min
U1	—	—
U2	0 (*see* Note 1)	27
U3	0	50
	–20 (*see* Note 2)	27

NOTES
1. Impact tests are only required if the chain cable is not heat treated.
2. Impact testing may be carried out at 0°C or minus 20°C.

2.13 Fittings for chain cables

2.13.1 Cable fittings are to be manufactured at an approved works.

2.13.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1 respectively. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

2.13.3 All fittings are to be manufactured to an approved manufacturing specification, and provision is to be made for tensile specimens and, where applicable, impact test specimens, *see* Table 10.2.3. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.2.1.

2.13.4 The test samples are to be prepared in accordance with 2.4.3 or 2.5.4 as applicable. The test specimens are to be subjected to heat treatment with the fittings they represent.

2.13.5 For mechanical testing, a batch is defined as fittings of the same grade, size and heat treatment furnace load and is to have originated from a single cast heat of steel.

2.13.6 Mechanical tests of pins are to be taken in accordance with 3.8.15.

2.13.7 Fittings such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade U2. The welded construction of fittings may also be approved providing that full details of the manufacturing process and the heat treatment are submitted.

2.13.8 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended. These include shackles, swivels, swivel shackles, enlarged links and end links. Anchor shackles, however, are to be tested in combination with the anchor, *see* 1.4.

2.13.9 The appropriate breaking load is to be applied for a minimum of 30 seconds to at least one item out of every batch of up to 25 detachable links, shackles, swivels, swivel shackles, enlarged end links and end links and at least one item out of every batch of up to 50 for lugless (Kenter) shackles. The item tested is to be destroyed and not used as part of an outfit. For the purposes of break load testing, a batch of accessories is to consist of:

(a) the same accessory type, grade and size;
(b) the same rolling or forging or casting process; and
(c) accessories that are heat treated together in the same furnace.

2.13.10 Where a break load batch as defined in 2.13.9 requires a normalise or normalise and temper heat treatment, the size of accessories may vary within a batch provided that the heat treatment cycle is chosen to satisfy the accessory with the largest cross-section size. The batch may consist of more than one steel-making heat provided that the two accessories are break tested, one with the largest cross-section size and one with the smallest cross-section size.

2.13.11 Where a break load batch as defined in 2.13.9 requires a quench and temper heat treatment, the size of the accessories within the batch is to be the same and is limited to the same steel-making heat.

2.13.12 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

2.13.13 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.

2.13.14 Where items of increased dimensions are used or if material of a higher grade than is specified is used, the breaking load is to be applied to each item, and the items so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load of the chain cable with which they are to be used.

2.13.15 LR may waive the breaking load test provided that:

(a) the breaking load test has been completed satisfactorily during approval testing, and
(b) the tensile and impact properties of each manufacturing batch are proved and
(c) the accessories are subjected to suitable non-destructive testing.

2.13.16 All testing is to be carried out in the presence of the Surveyor and to his satisfaction.

2.13.17 The following tolerances are applicable to accessories:

Nominal diameter: plus 5 per cent, minus 0 per cent
Other dimensions: ±2,5 per cent
The radii of all machined corners are to be not less than 0,03 times the nominal chain diameter.

2.13.18 All fittings are to be stamped in accordance with 2.15.

2.14 Substitute single links

2.14.1 Single links to connect lengths of chain cable or to substitute for defective links, without the necessity for re-heat treatment of the whole cable length, are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and the tests are to be made on the maximum size of chain for which approval is sought. Re-approval is required annually.

2.14.2 Manufacture and heat treatment of the substitute link are not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

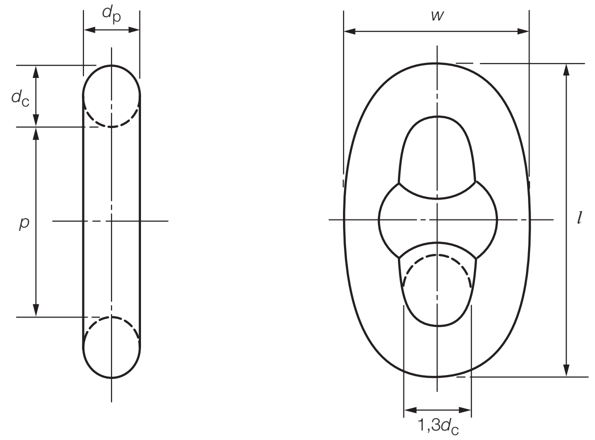
2.14.3 The steel bar used is to conform with the specification for the chain in accordance with Ch 3,9.

2.14.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

2.14.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

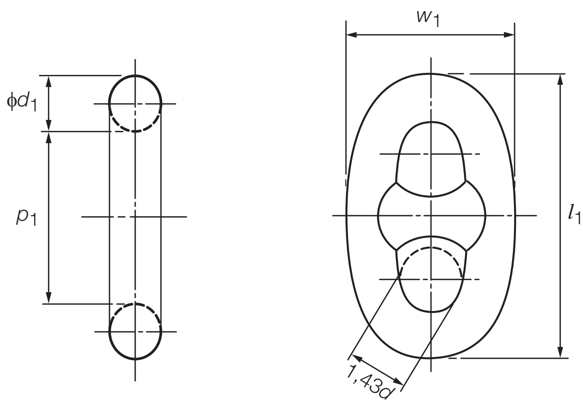
2.14.6 Every substitute link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated, as detailed in Table 10.2.4.

2.14.7 Each substitute link is to be stamped on the stud with the identification marks listed in 2.15.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.



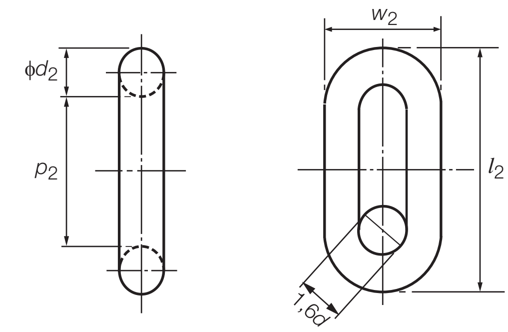
d = nominal diameter $\left(\dfrac{d_c + d_p}{2}\right)$
d_c = nominal diameter at crown measured in plane of link
d_p = nominal diameter at crown measured perpendicular to plane of link
l = $6d_c$
p = $4d_c$
w = $3{,}6d_c$ to the nearest millimetre

Fig. 10.2.2 Common link



d = nominal diameter of common stud link
d_1 = nominal diameter of enlarged stud link = $1{,}1d$
l_1 = $6d_1 \approx 6{,}6d$
p_1 = $4d_1 \approx 4{,}4d$
w_1 = $3{,}6d_1 \approx 3{,}96d$

Fig. 10.2.3 Enlarged link



d = nominal diameter of common stud link
d_2 = nominal diameter of end link = $1{,}2d$ ($d_2 = 1{,}2d$)
l_2 = $p_2 + 2d_2 \approx 6{,}75d$
p_2 = $3{,}65d_2 \approx 4{,}35d$
w_2 = $3{,}3d_2 \approx 4d$

Fig. 10.2.4 End link

2.15 Identification

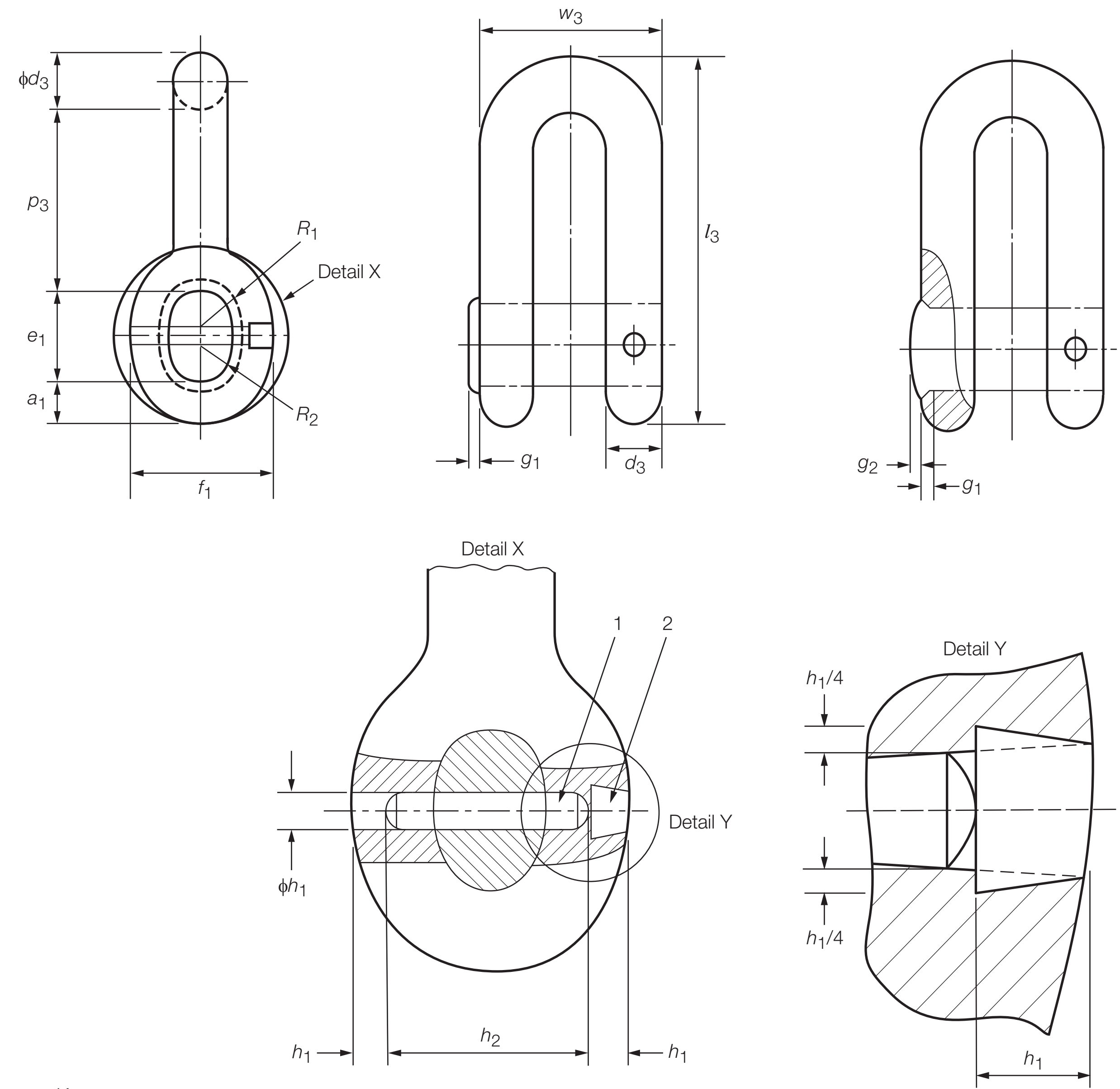
2.15.1 All lengths of Grades U1, U2 and U3 cable and all fittings are to be stamped with the following identification marks:
(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of certificate.
(c) Proof load and grade of chain.
(d) Surveyor's personal stamp.
(e) Each length of chain cable is to be stamped on both ends.

2.16 Certification

2.16.1 An LR certificate is to be issued for chain cable only, fittings only or chain cable with associated fittings.

2.16.2 Each test certificate is to include the following particulars for all items included on the certificate:
(a) Manufacturer's name.
(b) Purchaser's name and order number.
(c) Description and dimensions.
(d) Grade of chain cable.
(e) Identification mark which will enable the full history of the chain or fitting to be traced.
(f) Chemical composition.
(g) Details of heat treatment.
(h) Mechanical test results.
(j) Breaking test load.
(k) Proof load.

2.16.3 Where appropriate, the certificate is to include a list of all substitute links together with their grade of steel, the name of the steelmaker, the heat number and the purchase order number.

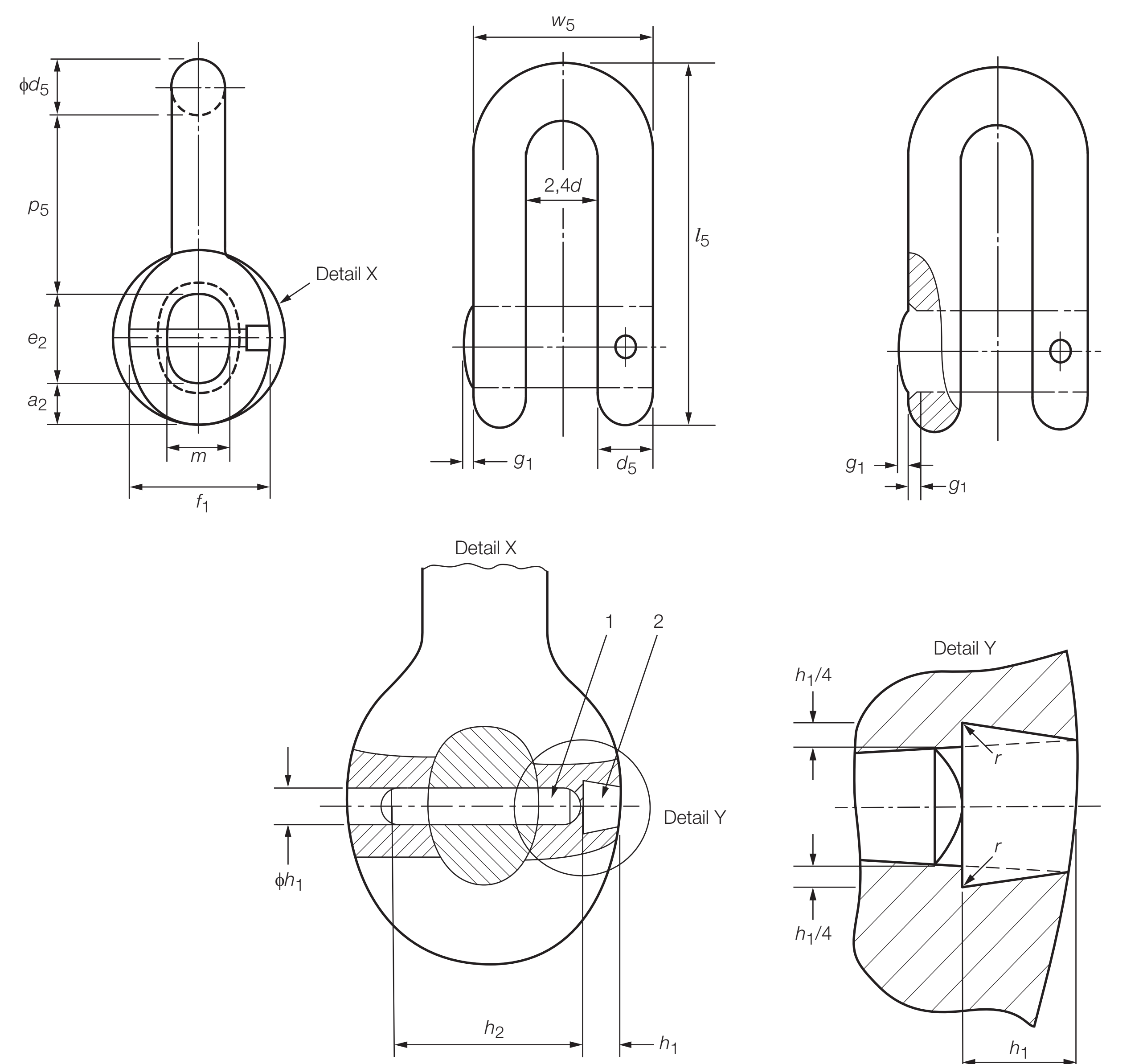


Key
1 retaining pin
2 dovetail chamber

d = nominal diameter of common stud link
d_3 = nominal diameter of joining shackle = 1,3d
l_3 = 7,1d
p_3 = $l_3 - (d_3 + a_1 + e_1)$ = 3,4d
w_3 = 4d
a_1 = 0,8d
e_1 = 1,6d

f_1 = 2,8d
g_1 = 0,2d
g_2 = 0,1d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
R_1 = 0,6d
R_2 = 0,5d

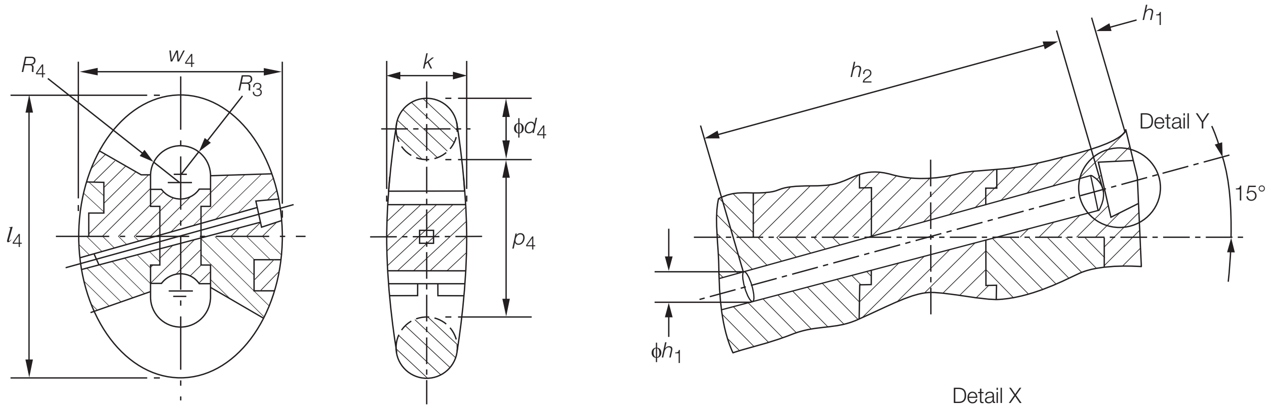
Fig. 10.2.5 Dee shackle

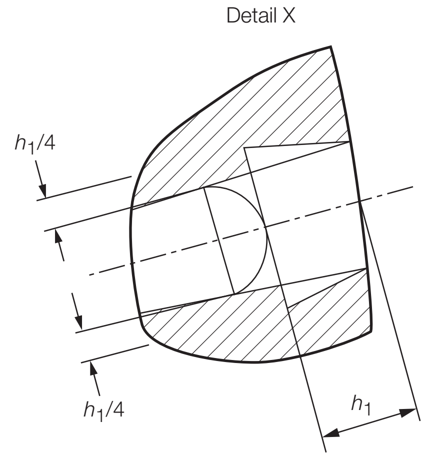


Key
1 retaining pin
2 dovetail chamber

d = nominal diameter of common stud link
d_5 = nominal diameter of end shackle = 1,4d
l_5 = 8,7d
p_5 = $l_5 - (d_5 + a_2 + e_2)$ = 4,5d
w_5 = 5,2d
a_2 = 0,9d
e_2 = 1,8d
f_2 = 3,1d
g_1 = 0,2d
g_2 = 0,1d
m = 1,4d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin

Fig. 10.2.6 End shackle



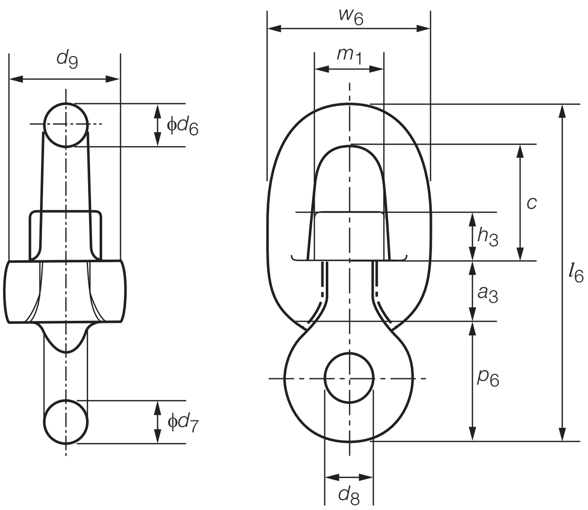


Key

Detail X = dovetail chamber for retaining pellet

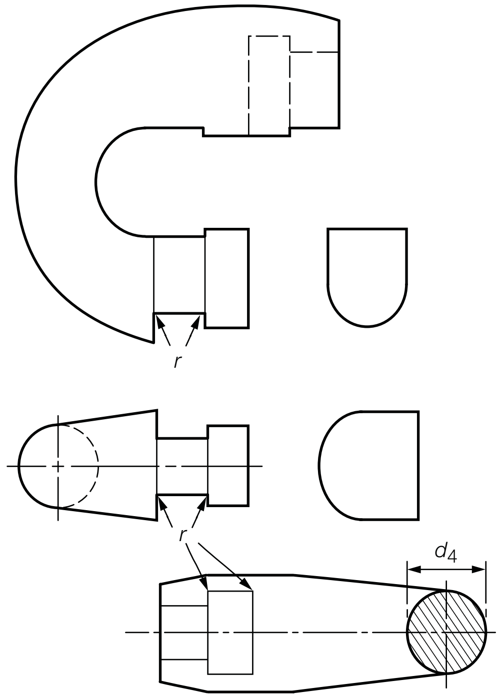
d = nominal diameter of common stud link
d_1 = nominal diameter of Kenter type joining shackle = d
l_4 = $6d$
p_4 = $4d$
w_4 = $4{,}2d$
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
k = $1{,}52d$
R_3 = $0{,}67d$
R_4 = $1{,}83d$

Fig. 10.2.7 Lugless shackle



d = nominal diameter of common stud link
d_6 = nominal diameter of swivel = $1{,}2d$
l_6 = $9{,}7d$
p_6 = $d_9 = 3{,}4d$
w_6 = $4{,}7d$
d_7 = $1{,}1d$
a_3 = $1{,}75d$
m_1 = $2d$
h_3 = $d_8 = 1{,}4d$
c = $3{,}35d$

Fig. 10.2.8 Swivel



The radii indicated by r are to be not less than 0,03 x d_4

Fig. 10.2.9 Lugless shackle of the Kenter type

Section 3
Stud link mooring chain cables

3.1 Scope

3.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5, of stud link chain intended for offshore mooring applications such as mooring of mobile offshore units, offshore loading systems and gravity based structures during fabrication.

3.1.2 Design of chain cables must be to a recognised Standard, such as ISO 1704; alternatively, the design may be specifically approved by LR.

3.1.3 In addition, chain cable conforming to the requirements of the current edition of API specification 2F is acceptable provided that it has been manufactured, inspected and tested under Survey by LR, and that the bar stock has also been certified by LR in accordance with Ch 3,9.

3.2 Manufacture

3.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for stud link chain cables is published separately by LR.

3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.

3.2.3 Approval is confined to a single works and is limited to one grade of cable made from bar from a nominated and approved supplier. Separate approvals are required if steel bar is supplied from more than one works and for other grades of cable, *see also* Ch 3,9.

3.2.4 Details of the method of manufacture and the specification of the steel, are to be submitted.

3.2.5 Offshore mooring chains are to be made in continuous lengths by flash-butt welding.

3.2.6 Bar material may be heated either by electric resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

3.2.7 The following welding parameters (as approved in the weld procedure) are to be controlled during welding of each link:
(a) platen motion;
(b) current as a function of time; and
(c) hydraulic pressure.
The controls are to be checked at least once every four hours.

3.2.8 The records of bar heating, flash-butt welding and heat treatment are to be made available to the Surveyor when required.

3.2.9 As far as practicable, consecutive links in all chain cable should originate from a single batch of bar stock (*see* Ch 3,9.6.1) and indicating marks should be stamped on the final link formed from one batch and the first link formed from a separate batch.

3.3 Dimensions and tolerances

3.3.1 The form and proportions of links and shackles are to be in accordance with ISO/1704, *see* Figs. 10.2.2 to 10.2.9. Link tolerances are to be in accordance with 3.3.2 to 3.3.6.

3.3.2 Diameter measured at the crown:
Minus 1 mm when $d_c \leq 40$ mm
Minus 2 mm when 40 mm $< d_c \leq 84$ mm
Minus 3 mm when 84 mm $< d_c \leq 122$ mm
Minus 4 mm when 122 mm $< d_c \leq 152$ mm
Minus 6 mm when 152 mm $< d_c \leq 184$ mm
Minus 7,5 mm when 184 mm $< d_c \leq 210$ mm
The plus tolerance must not exceed 5 per cent of the nominal diameter, and the cross-sectional area at the crown is to have no negative tolerance.

3.3.3 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

3.3.4 The maximum allowable tolerance on a length of five links measured in accordance with 2.11.1 is +2,5 per cent. No under-tolerance is permitted.

3.3.5 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.

3.3.6 The tolerances for common links are to be measured in accordance with Fig. 10.3.2.

3.3.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

3.3.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with Fig. 10.3.2 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

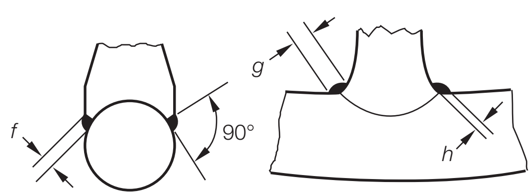
3.4 Studs

3.4.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed 0,23 per cent if the studs are to be welded in place.

3.4.2 Studs may be welded into grade R3 and R3S chains. The welding of studs into grade R4, R4S and R5 chain is not permitted unless specially approved.

3.4.3 In all cases where studs are welded into links, this is to be carried out in accordance with 2.7.

3.4.4 The size of the stud welds is to be in accordance with Fig. 10.3.1.



Dimension Designation	Nominal Dimension	Minus Tolerance
f	0,10*d*	0,01*d*
g	0,20*d*	0,02*d*
h	0,09*d*	0,01*d*

d = Nominal diameter of barstock

3450/02

Fig. 10.3.1
Dimensions and tolerances of stud welds

3.4.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within each length of chain are to be examined by magnetic particle inspection after proof load testing. Stress raising defects such as cracks, lack of fusion, gross porosity, and undercuts exceeding 1 mm are not permitted; if any such defects are found, then all stud welds in that length of chain are to be examined by means of magnetic particle inspection.

3.4.6 Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests. The combined effect of shape and depth of the impression of the stud in the link is not to cause any harmful notch effect or stress concentration.

3.5 Heat treatment of completed chain cables

3.5.1 The chain is to be normalised, normalised and tempered or quenched and tempered in accordance with the specification approved by LR.

3.5.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.5.3 The temperature and time, or temperature and chain speed, are to be controlled and continuously recorded.

3.5.4 Heat treatment is to be carried out prior to the proof loading and breaking tests.

3.5.5 Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).

3.6 Testing of completed chain cables

3.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

3.6.2 The entire length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable.

3.6.3 Care should be taken to obtain a uniform stress distribution in the links being tested.

3.6.4 The chain is to be shot or sand blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection.

3.6.5 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding.

3.6.6 All flash butt welds, including the area gripped by the clamping dies, are to be examined by magnetic particle inspection. The area is to be free from cracks, lack of fusion, gross porosity and any other stress concentrations.

3.6.7 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

3.6.8 All flash butt welds are also to be examined by ultrasonic inspection and are to be free from defects such as internal cracks or lack of fusion.

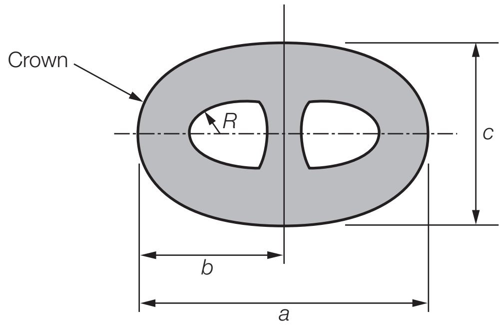
3.6.9 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

3.6.10 All non-destructive examination operators are to be qualified to a minimum Level II, qualified in accordance with a recognised standard.

3.6.11 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.11.12. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

Fig. 10.3.2 Stud link chain cable common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link half length	*a**/2	0,10*d*	0,10*d*
c	Link width	3,6*d*	0,09*d*	0,09*d*
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0,65*d*	0	—

Symbols

d = nominal diameter of chain
*a** = actual link length

3.6.12 The links held in the end blocks may be excluded from these measurements.

3.6.13 If the length over five links is less than the nominal, the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and that only random lengths of the chain need to be stretched.

3.6.14 Loads used for plastic straining to set studs are not to exceed those approved in qualification tests.

3.6.15 Checks of all other dimensions are to be made on at least five per cent of the links in the cable.

3.6.16 If any link fails to meet the dimensional tolerance requirements (*see* 3.3), measurements are to be made on 20 more links on each side of the incorrect one. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

3.6.17 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain, and connecting common links complying with the requirements of 3.7 inserted in their places.

3.6.18 The chain is then to be subjected to a further proof load test and re-examined.

3.6.19 The number of connecting common links which may be used to replace defective links is not to exceed three in any 100 m length of chain. The number and type of joining shackles which may be used are to be subject to the written agreement of the end user.

3.6.20 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 3.6.21 and 3.6.22. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables. The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.

3.6.21 In addition to the requirements of 3.6.2, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with Table 10.3.2. Extra links are to be provided for the mechanical tests detailed in 3.6.25. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

Table 10.3.1 Test loads for mooring chain cables *(continued)*

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
50	1480	1480	2230	1800	1740	2490	2160	1920	2740	2400	2130	3040	2510	2230	3200
52	1594	1594	2402	1939	1874	2682	2327	2068	2952	2585	2295	3275	2704	2402	3447
54	1712	1712	2580	2083	2013	2881	2499	2222	3170	2777	2465	3517	2904	2580	3703
56	1834	1834	2764	2231	2156	3086	2677	2380	3396	2974	2640	3768	3111	2764	3966
58	1960	1960	2953	2383	2304	3297	2860	2542	3628	3178	2820	4025	3323	2953	4237
60	2089	2089	3147	2540	2455	3514	3048	2710	3867	3387	3006	4290	3542	3147	4516
62	2221	2221	3347	2701	2611	3737	3242	2881	4112	3602	3196	4562	3767	3347	4802
64	2357	2357	3551	2867	2771	3965	3440	3058	4364	3822	3392	4841	3997	3551	5096
66	2496	2496	3761	3036	2935	4200	3643	3238	4621	4048	3593	5127	4233	3761	5397
68	2639	2639	3976	3209	3102	4440	3851	3423	4885	4279	3798	5420	4475	3976	5706
70	2785	2785	4196	3387	3274	4685	4064	3613	5156	4516	4008	5720	4723	4196	6021
73	3010	3010	4535	3660	3538	5064	4392	3904	5572	4881	4331	6182	5104	4535	6507
76	3242	3242	4884	3942	3811	5454	4731	4205	6001	5257	4665	6658	5498	4884	7009
78	3400	3400	5123	4135	3997	5720	4962	4411	6295	5514	4893	6984	5766	5123	7351
81	3643	3643	5490	4431	4283	6130	5317	4726	6745	5908	5243	7484	6179	5490	7877
84	3893	3893	5866	4735	4577	6550	5682	5051	7208	6313	5603	7997	6602	5866	8418
87	4149	4149	6252	5046	4878	6981	6056	5383	7682	6729	5972	8523	7037	6252	8971
90	4412	4412	6647	5365	5187	7422	6439	5723	8167	7154	6349	9062	7482	6647	9539
92	4590	4590	6916	5582	5396	7722	6699	5954	8497	7443	6606	9428	7784	6916	9924
95	4862	4862	7326	5913	5716	8180	7096	6307	9001	7884	6997	9987	8246	7326	10512
97	5047	5047	7604	6138	5933	8490	7365	6547	9343	8184	7263	10366	8559	7604	10911
100	5328	5328	8028	6480	6264	8964	7776	6912	9864	8640	7668	10944	9036	8028	11520
102	5519	5519	8315	6712	6488	9285	8054	7159	10217	8949	7942	11336	9359	8315	11932
105	5809	5809	8753	7065	6829	9773	8478	7536	10754	9420	8360	11932	9851	8753	12560
107	6005	6005	9048	7304	7060	10103	8764	7790	11118	9738	8643	12335	10184	9048	12984
111	6404	6404	9650	7789	7529	10775	9347	8308	11856	10385	9217	13154	10861	9650	13847
114	6709	6709	10109	8159	7887	11287	9791	8703	12420	10879	9655	13780	11378	10109	14506
117	7018	7018	10574	8535	8251	11807	10242	9104	12993	11380	10100	14415	11902	10574	15174
120	7331	7331	11047	8916	8619	12334	10700	9511	13573	11889	10551	15059	12434	11047	15852
122	7542	7542	11365	9173	8868	12690	11008	9785	13964	12231	10855	15493	12792	11365	16308
124	7755	7755	11686	9432	9118	13048	11319	10061	14358	12576	11161	15930	13153	11686	16768
127	8078	8078	12171	9824	9497	13591	11789	10479	14955	13099	11626	16592	13700	12171	17466
130	8404	8404	12663	10221	9880	14139	12265	10903	15559	13628	12095	17262	14253	12663	18171
132	8623	8623	12993	10488	10138	14508	12585	11187	15965	13984	12411	17713	14625	12993	18645
137	9178	9178	13829	11162	10790	15441	13395	11906	16992	14883	13209	18852	15565	13829	19844

Table 10.3.1 Test loads for mooring chain cables (*conclusion*)

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
142	9741	9741	14677	11847	11452	16388	14216	12637	18033	15796	14019	20008	16520	14677	21061
147	10311	10311	15536	12540	12122	17347	15048	13376	19089	16720	14839	21179	17487	15536	22294
152	10887	10887	16405	13241	12800	18317	15890	14124	20156	17655	15669	22363	18464	16405	23540
157	11469	11469	17282	13949	13484	19297	16739	14879	21234	18599	16507	23559	19452	17282	24799
162	12056	12056	18166	14663	14174	20284	17596	15641	22320	19551	17351	24764	20447	18166	26068
167	12647	12647	19056	15381	14869	21278	18458	16407	23414	20508	18201	25977	21448	19056	27345
172	13240	13240	19950	16103	15566	22276	19324	17177	24513	21471	19055	27196	22455	19950	28628
177	13836	13836	20847	16827	16267	23278	20193	17949	25615	22437	19912	28420	23465	20847	29915
182	14433	14433	21746	17553	16968	24282	21064	18723	26720	23404	20771	29645	24477	21746	31205
187	15029	15029	22646	18279	17670	25286	21935	19498	27825	24372	21630	30871	25489	22646	32496
192	15626	15626	23544	19004	18371	26289	22805	20271	28929	25339	22488	32096	26500	23544	33785
197	16220	16220	24440	19727	19070	27290	23673	21043	30029	26303	23344	33317	27509	24440	35071
202	16813	16813	25332	20448	19766	28286	24537	21811	31126	27264	24196	34534	28513	25332	36351
207	17401	17401	26220	21164	20459	29277	25397	22575	32216	28219	25044	35744	29512	26220	37625
210	17753	17753	26749	21591	20872	29868	25910	23031	32867	28788	25550	36465	30108	26749	38385

Grade R3		
Proof test load	Stud link chain	$0{,}0148d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0148d^2 (44 - 0{,}08d)$
Break test load		$0{,}0223d^2 (44 - 0{,}08d)$
Grade R3S		
Proof test load	Stud link chain	$0.0180d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0174d^2 (44 - 0{,}08d)$
Break test load		$0{,}0249d^2 (44 - 0{,}08d)$
Grade R4		
Proof test load	Stud link chain	$0{,}0216d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0192d^2 (44 - 0{,}08d)$
Break test load		$0{,}0274d^2 (44 - 0{,}08d)$
Grade R4S		
Proof test load	Stud link chain	$0{,}0240d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0213d^2 (44 - 0{,}08d)$
Break test load		$0{,}0304d^2 (44 - 0{,}08d)$
Grade R5		
Proof test load	Stud link chain	$0{,}0251d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0223d^2 (44 - 0{,}08d)$
Break test load		$0{,}0320d^2 (44 - 0{,}08d)$

3.6.22 Breaking test specimens are to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load.

3.6.23 If a breaking test specimen fails, two further specimens are to be cut from the same sampling length and both are to be subjected to the breaking test load. If one of the re-test specimens fails the length is to be rejected. All the broken links are to be subjected to an investigation into the cause of failure. LR will then decide which lengths of chain can be accepted and on further action.

3.6.24 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

3.6.25 One tensile and three sets of Charpy V-notch impact test specimens are to be taken from links cut from the heat treated and proof loaded chain at intervals no greater than those indicated in Table 10.3.2 provided that every cast is sampled. The tensile specimen and one set of impact specimens are to be taken from the side of the link opposite the weld. One set of impact test specimens is to have the notches positioned at the centre of the flash butt weld and the third set is to be taken from the bend. All the specimens are to be taken from positions in accordance with Fig. 10.3.3.

3.6.26 The frequency of testing at the link bends may be reduced at the discretion of LR provided it can be verified that the required toughness is achieved consistently.

3.6.27 The results of the mechanical tests are to comply with the requirements of Table 10.3.3.

3.6.28 If the tensile test requirements are not achieved, two further specimens from the same sample are to be tested. The related length of chain will be considered acceptable if both re-test specimens meet the requirements but failure of either of the re-test specimens will result in rejection of the sampling length of chain represented by the tests.

3.6.29 If the impact test requirements are not achieved, re-tests may be carried out in accordance with Ch 1,2.4. Failure to meet the re-test requirements will result in rejection of the sampling length of chain represented by the tests.

3.6.30 The mass per unit length of stud link mooring cable is to comply with Table 10.3.4.

3.7 Connecting common links or substitute links

3.7.1 Single links to connect lengths of heat treated chain cable or to substitute for test links or defective links without the necessity for re-heat treatment of the whole length of cable are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and tests are to be made on the maximum size of chain for which approval is sought.

Table 10.3.2 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
Min. — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322
176 — 186	346
187 — 199	370
199 — 210	395

NOTE
If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.

3.7.2 Manufacture and heat treatment of the connecting common link is not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.7.3 The steel bar used is to conform with the specification for the chain and approved by LR in accordance with Ch 3,9.

3.7.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

3.7.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

3.7.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in Table 10.3.1.

3.7.7 Every connecting common link is to be inspected in accordance with 3.6.5 to 3.6.10.

3.7.8 A second identical link is to be made for mechanical tests which are to be in accordance with 3.6.25. This test link is also to be inspected in accordance with 3.7.7.

3.7.9 Each connecting common link is to be stamped on the stud with the identification marks listed in 3.9.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

3.8 Fittings for offshore mooring chain

3.8.1 Cable fittings are to be manufactured at an approved works. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackles.

Table 10.3.3 Mechanical properties of chain cable materials

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation % minimum	Reduction of area % minimum (*See* Note 3)	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
R3	410 (*See* Note 1)	690 minimum (*See* Note 1)	17	50	0 –20 (*See* Note 2)	60 40	50 30
R3S	490 (*See* Note 1)	770 minimum (*See* Note 1)	15	50	0 –20 (*See* Note 2)	65 45	53 33
R4	580 (*See* Note 1)	860 minimum (*See* Note 1)	12	50	–20	50	36
R4S (*See* Note 4)	700 (*See* Note 1)	960 (*See* Note 1)	12	50	–20	56	40
R5 (*See* Note 4)	760 (*See* Note 1)	1000 (*See* Note 1)	12	50	–20	58	42

NOTES
1. The ratio of yield strength to tensile strength should not exceed 0,92.
2. Testing may be carried out at either 0°C or –20°C.
3. For cast fittings, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grades R4, R4S and R5.
4. The maximum hardness for Grade R4S is to be HB330, and for Grade R5 is to be HB340.

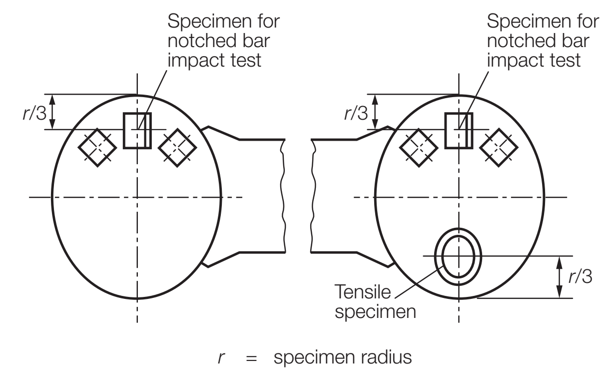


Fig. 10.3.3 Sampling of chain links

3.8.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1, and 3.8.3 to 3.8.6. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

3.8.3 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.

3.8.4 The austenite grain size of steel used for fittings must be 6 or finer as measured in accordance with ASTM E112.

3.8.5 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.

Table 10.3.4 Mass per unit length of chain cable

Nominal chain diameter (mm)	Mass per unit length $0{,}0291d^2$ (kg/m)
50	73
55	88
60	105
65	123
70	143
75	164
80	186
85	210
90	236
95	263
100	291
105	321
110	352
115	385
120	419
125	455
130	492
135	530
140	570
145	612
150	655
155	699
160	745
165	792
170	841
175	891
180	943
185	996
190	1051
195	1107
200	1164
205	1223
210	1283

3.8.6 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.

(b) Macro etching on representative sample, in accordance with ASTM E381 or equivalent, this must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final accessory documentation.

3.8.7 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.

3.8.8 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.3.3.

3.8.9 For fittings for mooring chain, a batch is defined as fittings from the same steel-making heat that have been heat treated together in the same furnace.

3.8.10 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with 3.8.14.

3.8.11 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in Fig. 10.3.4, with the Charpy impact test specimens on the outside radius.

3.8.12 The test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in Fig. 10.3.4.

3.8.13 For fittings with complex geometries the locations of test pieces taken are to be approved by LR.

3.8.14 Where fittings are produced in small batches (less than 5) alternative testing may be approved; a proposal must be submitted in a written procedure for consideration.

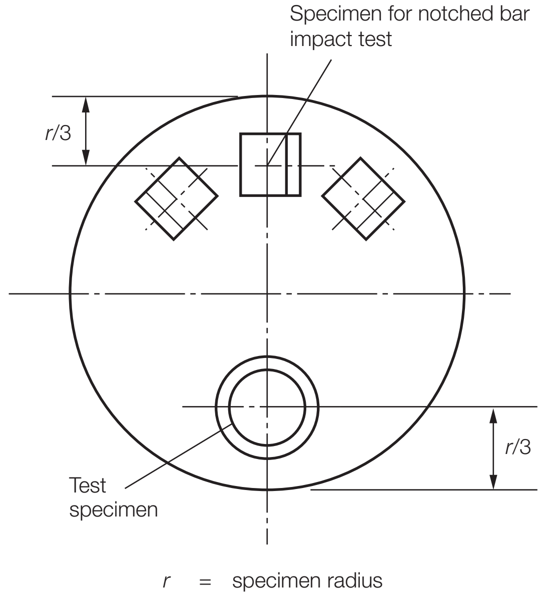


Fig. 10.3.4
Sampling of steel bars, forgings and castings

3.8.15 Mechanical tests of pins are to be taken as shown in Fig. 10.3.5 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in Fig. 10.3.5.

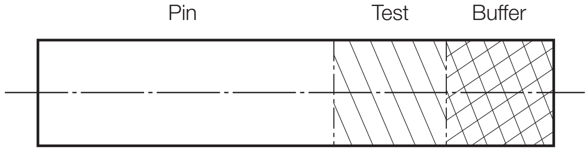


Fig. 10.3.5
Buffer and test piece location for pins

3.8.16 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.8.17 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see* Table 10.3.1. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.8.18 The appropriate breaking load as required by Table 10.3.1 is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

3.8.19 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other accessories in the batch. If this can be demonstrated then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

3.8.20 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing and submitted.

3.8.21 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

3.8.22 The following tolerances apply of the unmachined dimensions of all fittings;
(a) nominal diameter plus 5 per cent, minus 0 per cent; and
(b) other dimensions plus or minus 2,5 per cent.

3.8.23 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. All NDE is to be carried out in accordance with 3.6.9 and 3.6.10. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results; this statement is to include reference to the techniques used and the operator's qualifications.

3.8.24 All testing is to be carried out to the satisfaction and in the presence of the Surveyor.

3.8.25 Fittings of increased dimensions or higher grade material may be used subject to approval by LR.

3.8.26 Where fittings with increased dimensions, or fittings of a higher material grade are included in an outfit:
(a) each item must be successfully tested at the required breaking load for the chain cable for which it is intended; and
(b) items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which they are intended, and this has been verified by procedure tests.

3.9 Identification

3.9.1 Each length of chain is to be permanently marked with the following:
(a) LR and abbreviated name of LR's local office issuing the certificate.
(b) Certificate number (this may be abbreviated provided it is stated in the certificate).
(c) Grade and proof load of chain.

3.9.2 The chain is to be marked as follows:
(a) at each end (the marking should identify the leading and tail end of each chain),
(b) at intervals not exceeding 100 m,
(c) on all connecting common links or shackles and the immediately adjacent links,
(d) on the first and last common link of each individual heat used in the continuous length.

3.9.3 All identification marks are to be made on the studs and are to be permanent and legible throughout the expected service life of the chain.

3.10 Documentation

3.10.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length, and for each order for chain and fittings. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records, as well as any non-conformity, together with corrective action and repair work.

3.10.2 All documents, including reports and appendices, are to contain a reference to the relevant certificate number.

3.10.3 The chain manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

3.11 Certification

3.11.1 An LR certificate is to be issued for each continuous single length of chain, and each type of fitting, *see* Ch 1,3.1.

3.11.2 Each test certificate is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.
(k) The number and locations of all connecting common links and all marked links.

■ *Section 4* Studless mooring chain cables

4.1 Scope

4.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5 of studless flash butt welded chain cable intended for long term mooring applications.

4.1.2 The chain is generally expected to be deployed only once for a pre-determined service life.

4.1.3 Each studless chain link design will require to be approved by LR. The plan submitted for this approval is to include the minimum proof and breaking test loads, and the chain mass calculations.

4.2 Manufacture

4.2.1 All the requirements of 3.2, with the exception of that relating to studs, apply to the manufacture of studless mooring chain cables.

4.3 Shape and dimensions of links

4.3.1 The shape and dimensions of the links are to be in accordance with the approved design.

4.4 Dimensional tolerances

4.4.1 The dimensional tolerances of studless links are to be in accordance with the requirements of 3.3.1 to 3.3.7.

4.4.2 The tolerances for common links are to be measured in accordance with Fig. 10.4.1.

4.5 Heat treatment

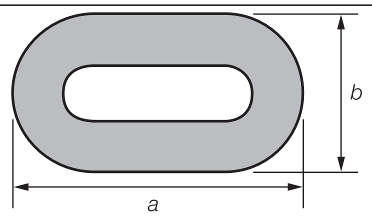
4.5.1 Heat treatment of the chain is to be in accordance with the requirements of 3.5.

4.6 Testing of completed chain

4.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

Fig. 10.4.1 **Studless chain cable common link tolerances**

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	—

Symbols

d = nominal diameter of chain

NOTE
Other dimensional ratios are subject to special approval.

4.6.2 The entire length of chain cable is to be subjected to a proof load test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and diameter of the chain, *see also* 4.1.3.

4.6.3 Inspection after proof load testing is to be in accordance with the requirements given in 3.6.3 to 3.6.20, excluding that related to checking of studs in 3.6.5.

4.6.4 In addition to the inspection of the flash butt welded areas as required in 3.6.6, the surfaces of the bends of at least 10 per cent of the links are to be examined by magnetic particle inspection and are to be free from cracks or other defects.

4.6.5 If stretching of links is required in order to maintain dimensional tolerances, the load applied is not to exceed the proof load by more than 10 per cent, and only random lengths of the chain need to be stretched.

4.6.6 Breaking load tests are to be carried out in accordance with 3.6.21 to 3.6.23 and Tables 10.3.1 and 10.3.2.

4.6.7 Alternative procedures to breaking load testing (*see* 3.6.24) are not permissible unless prior agreement is given by LR after special consideration.

4.6.8 Mechanical testing is to be carried out in accordance with 3.6.25 to 3.6.30 and Table 3.3.4.

4.6.9 The weight of the chain cable is to be in accordance with the approved plan.

4.7 Connecting or substitute links

4.7.1 Connecting links and substitute links are to be in accordance with the requirements of 3.7.

4.8 Fittings

4.8.1 Fittings for studless chain are to comply with the requirements of 3.8.

4.9 Identification

4.9.1 All chain and each fitting is to be identified in accordance with 3.9.1 and 3.9.2.

4.9.2 Identification marks are to be made on the outside of the straight part of the link, opposite the flash butt weld.

4.10 Certification

4.10.1 Certificates are to be issued in accordance with 3.11.

4.11 Documentation

4.11.1 Documentation in accordance with 3.11 is to be provided by the manufacturer.

■ *Section 5*
Short link chain cables

5.1 Scope

5.1.1 This Section gives the requirements for electrically welded steel short link chain cable for marine use but excluding those applications covered by the *Code for Lifting Appliances in a Marine Environment*.

5.1.2 Provision is made for grade M(4), as defined in ISO 1834.

5.2 Manufacture

5.2.1 Short link chain cables are to be manufactured at works approved by LR. A list of approved manufacturers for short link chain cable is published separately by LR.

5.2.2 The chain is to be supplied in either the normalised or quenched and tempered condition. Heat treatment is to be carried out prior to proof and breaking load testing.

5.2.3 The chain may be galvanised using a hot dipping process provided that this is carried out prior to proof and breaking load testing. If galvanised, it is recommended that the thickness of the zinc coating be not less than 70 microns.

5.2.4 Unless otherwise agreed, the finished chain is to be free from coatings other than zinc.

5.3 Bar material

5.3.1 Bars for the manufacture of short link chain cable are to be made and tested in accordance with the appropriate requirements of Ch 3,1 and to the requirements of an International or acceptable National Standard.

5.3.2 The bars are to be made at a works approved by LR.

5.3.3 The steel is to be fully killed and fine grain treated.

5.3.4 The steel is to have mechanical properties which will allow the chain to meet the mechanical test requirements of 5.4.7 and Table 10.5.1.

Table 10.5.1 Mechanical test requirements for short link chain cables

Chain diameter mm	Grade M(4)	
	Proof load kN	Breaking load minimum kN
5	7,9	15,8
6,3	12,5	25
7,1	15,9	31,8
8	20,2	40,4
9	25,5	51
10	29,5	63
11,2	31,5	79
12,5	49,1	98,2
14	63	126
16	81	162
18	102	204
20	126	252
22,4	158	316
25	197	394
28	247	494
32	322	644
36	408	816
40	503	1006
45	637	1274

5.4 Testing and inspection of chain cables

5.4.1 All chain cable of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

5.4.2 For chain of diameter less than 12,5 mm, other than steering chains, the manufacturer's tests will be acceptable.

5.4.3 After completion of all manufacturing processes, including heat treatment and galvanising, the whole of the chain is to be subjected to the appropriate proof load specified in Table 10.5.1.

5.4.4 The whole of the chain is to be inspected after the proof load test and is to be free from significant defects.

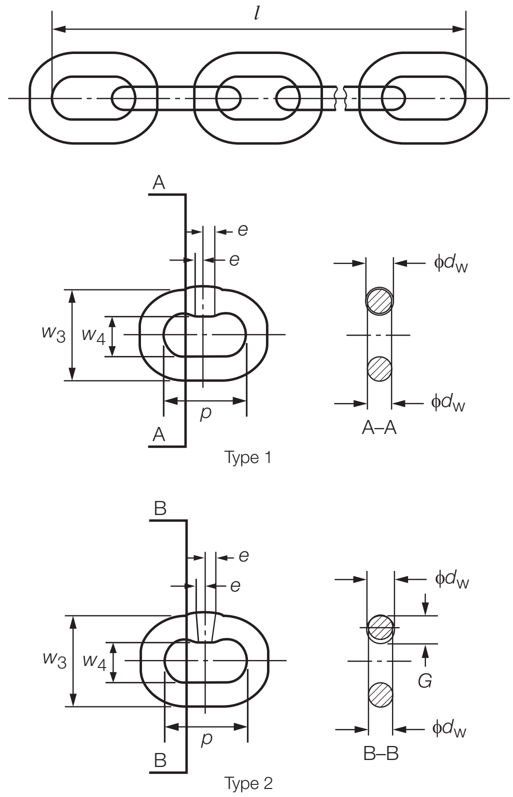
5.4.5 At least one sample, consisting of seven or more links, is to be selected by the Surveyor from each 200 m or less of chain for breaking load tests. Two additional links may be required for engagement in the jaws of the testing machine. These extra links are not to be taken into account in determining the total elongation, *see* 5.4.7.

5.4.6 The breaking load is to comply with the appropriate requirements of Table 10.5.1.

5.4.7 The total elongation of the breaking load sample at fracture, expressed as a percentage of the original inside length of the sample after proof loading, is to be not less than 20 per cent.

5.5 Dimensions and tolerances

5.5.1 The form and proportions of links are to be in accordance with Fig. 10.5.1.



l = multiple pitch length
p = pitch (internal link length)
d_n = measured diameter of the material, except at the weld
d_w = measured diameter of the material at the weld (Type 1) or weld dimension perpendicular to the plane of the link (Type 2)
G = dimension in other planes as per individual chain specification (Type 2)
e = length affected by welding, on either side of the centre link
w_1 = internal link width away from the weld
w_2 = external link width away from the weld
w_3 = external link width over the weld
w_4 = internal link width at the weld

Fig. 10.5.1 Form and proportions of links

5.5.2 Manufacturing tolerances are to be within the following limits:

Nominal diameter, d_n	± 5%
Pitch of chain, p_1	± 3%
Length measured over 11 links, l	± 2%
Inside width, w_1	1,35d_n minimum
Outside width, w	3,6d_n maximum

The tolerances are to apply after galvanising. All measurements are to be taken after proof testing.

5.6 Identification

5.6.1 All lengths of cable are to be stamped with the following identification marks:

(a) Inspector's mark and date.
(b) Reference mark or number of certificate.
(c) Manufacturer's mark or name.
(d) Chain cable quality mark, M, is to be stamped on at least each twentieth link or at intervals of one metre, whichever is the lesser distance.

5.6.2 Where the inspection is performed under LR's supervision, the inspector's mark and date are to be replaced by LR and the abbreviated name of LR's local office issuing the certificate.

5.7 Certification

5.7.1 The manufacturer is to supply the Surveyor with a certificate stating compliance with an appropriate ISO standard, and also, in the event of the requirements of 5.4 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognised proving establishment.

5.7.2 Each test certificate is to include the following particulars:

(a) the quality and description of chain,
(b) identification mark,
(c) nominal size of chain,
(d) proof load,
(e) breaking load,
(f) total elongation at fracture,
(g) where appropriate, the name of the proving establishment.

■ *Section 6* Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, the construction is to be in accordance with Table 10.6.1. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's plant and method of production are to be approved by LR. A list of approved manufacturers of steel wire ropes is published annually in the *List of Approved Manufacturers of Materials*.

6.2.3 For shaped wire, for example, for large diameter ropes for permanent mooring, where there are no established Standards, the manufacturer is to provide evidence by way of test reports that specifications have been developed and agreed with the purchaser and LR for the purposes intended.

6.3 Steel wire for ropes

6.3.1 Steel wire is to be of homogeneous quality, uniform strength and free of defects likely to impair the manufacture and performance of the rope.

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to be 1420, 1570, 1770 or 1960 N/mm^2. The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength.

Table 10.6.1 Recommended rope construction

Purpose	Construction of rope			Construction of strands
	Strands	Wires	Core	
Stream wires, towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
Towlines and mooring lines used in association with mooring winches	6	31	7 x 7 wire rope	12 over (6 + 6) over 6 over 1
	6	36	7 x 7 wire rope	14 over (7 + 7) over 7 over 1
	6	41	7 x 7 wire rope	16 over (8 + 8) over 8 over 1

6.3.3 For new rope construction, the manufacturer is to carry out prototype testing suitable for the application of the rope and this is to include tests on wire used for the construction.

6.3.4 Tensile and torsion tests, coating, and adhesion (wrap) tests are to be carried out on wire used for the manufacture of rope.

6.3.5 At least 10 per cent of the spools used for the manufacture of the strand are to be tested. The manufacturer is to demonstrate that tests have been carried out on at least one wire intended for each of the outer and inner strands, and for each diameter and grade used.

6.3.6 The heat number, wire diameter and strength of wire used for a particular construction are to be recorded by the manufacturer.

6.3.7 Torsion tests are to be carried out on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched).

6.3.8 The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in Table 10.6.2.

6.3.9 The galvanised wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with Table 10.6.2.

Table 10.6.2 Torsion test

Diameter coated wire mm	Minimum number of twists					
	Grade 2		Grade 1 or 3			
	Minimum strength N/mm^2		Minimum strength N/mm^2			
	1570	1770	1420	1570	1770	1960
<1,3	19	18	29	26	23	23
≥1,3 <2,3	18	17	26	24	21	21
≥2,3 <3,0	16	14	24	22	—	19
≥3,0 <4,0	12	10	20	18	—	17
≥4,0 <4,6	—	—	18	16	—	—
≥4,6 <5,0	—	—	16	14	—	—
≥5,0 <6,0	—	—	14	11	—	—

NOTE
The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.

6.3.10 Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in Table 10.6.3. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanising is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.

Table 10.6.3 Zinc coating

Diameter of coated wire mm	Zinc coating, minimum g/m^2		
	Grade1	Grade 2	Grade 3
≥0,20 <0,25	—	30	20
≥0,25 <0,33	—	45	30
≥0,33 <0,40	—	60	30
≥0,40 <0,50	60	75	40
≥0,50 <0,60	70	90	50
≥0,60 <0,80	85	110	60
≥0,80 <1,00	95	130	70
≥1,00 <1,20	110	150	80
≥1,20 <1,50	120	165	90
≥1,50 <1,90	130	180	100
≥1,90 <2,50	—	205	110
≥2,50 <3,20	—	230	125
≥3,20 <4,00	—	250	135

6.3.11 The mass per unit area of the zinc coating is to be determined in accordance with a recognised National or International Standard.

6.3.12 Zinc coating tests are to be carried out for each designated grade of wire. The manufacturer is to demonstrate that the coatings are continuous and uniform and suitable for the intended purpose.

6.3.13 Unless otherwise specified by the purchaser, zinc coating tests are to be carried out on the wire prior to stranding.

6.3.14 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in Table 10.6.4. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.

Table 10.6.4 Wrap test for adhesion of coating

Coating	Diameter of coated wire mm	Maximum ratio of mandrel to wire diameter
Grade 1 and 2	<1,5	4
	≥1,5	6
Grade 3	<1,5	2
	≥1,5	3

6.4 Tests on completed ropes

6.4.1 Every length of wire rope is to be subjected to a breaking strength test.

6.4.2 A sample of sufficient length is to be provided for the breaking load test. The rope ends are to be enclosed in a suitable socket. Testing is to be carried out in accordance with a recognised National or International Standard.

6.4.3 The rope may be subject to cyclic loading for bedding purposes prior to testing. The rope is to be tested at a suitable strain rate in accordance with a recognised National or International Standard.

6.4.4 The load is to be applied until one wire break is witnessed or 130 per cent of the minimum breaking load is recorded. The maximum recorded load is to be reported by the manufacturer.

6.4.5 Tests in which a breakage occurs adjacent to and as a result of damage from the grips are to be rejected, if the applied load is less than the specified minimum requirement. The rope is to be retested to withstand the agreed minimum breaking load.

6.4.6 With the exception of offshore mooring ropes, consideration may be given to determining the breaking load by summation or aggregating actual test results on individual wires, if facilities are not available for undertaking a breaking test on a production basis. A suitable spin factor or lay-up deduction allowance in accordance with a recognised National or International Standard for the applicable rope diameter, designated grade and construction is to be applied.

6.4.7 Where spin factors or lay-up deduction allowances are proposed by the manufacturer, a report on suitable cyclic load testing of prototype ropes of the same construction, strength and diameter is to be approved by LR. In addition, the manufacturer is to show that a satisfactory breaking load test has been carried out in the previous two years, and witnessed by LR for the same rope construction, diameter and designated grade.

6.4.8 LR may give special consideration to spin factors or lay deductions based on data extrapolated from smaller diameter ropes of the same construction, provided that these ropes have been tested in accordance with 6.4.7.

6.4.9 All data arising from smaller diameter ropes for the extrapolation in 6.4.8 are to have been derived from tests carried out within two years of the manufacture of the larger diameter rope.

6.4.10 The finished rope is to have no more than one wire connecting weld in any length of 18*d*, where *d* is the diameter of the rope.

6.5 Inspection

6.5.1 A report on dimensional and visual examination is to be presented to the Surveyor by the manufacturer. The dimensions and discard criteria are to comply with an agreed National or International Standard.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.7 Certification

6.7.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

6.7.2 Each test certificate is to contain the following particulars:

- Purchaser's name and order number.
- Details of the rope construction.
- Core material.
- Grade of zinc coating.
- Mechanical test results.
- Adhesion test results.
- Dimensions.
- Method of breaking load testing.
- Breaking load.

■ *Section 7* Fibre ropes

7.1 Manufacture

7.1.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic (man-made) fibres. They may be three-strand (hawser laid), four-strand (shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

7.1.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognised National Standard.

7.1.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognised standard.

7.1.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

7.2 Tests of completed ropes

7.2.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

7.2.2 The minimum test length and the initial test load are to be as given in Table 10.7.1. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 10.7.1 until it breaks.

7.2.3 The actual breaking load is to be not less than that given in an appropriate National Standard.

Table 10.7.1 Breaking load test

Material	Test length mm minimum	Initial load % (*see* Note)	Rate of straining mm/min
Natural fibre	1800	2	150 ± 50
Synthetic fibre	900	1	100 max.

NOTE
Percentage of specified minimum breaking load.

7.2.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

7.2.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, LR will consider alternative methods of testing.

7.3 Identification

7.3.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

7.4 Certification

7.4.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

7.4.2 Each test certificate is to include the following particulars:
- Manufacturer's name.
- Purchaser's name and order number.
- Rope type.
- Dimensions.
- Test length.
- Rate of straining.
- Breaking load.

Approval of Welding Consumables

Section

■ *Section 1* General

1.1 Scope

1.1.1 Provision is made in this Chapter for the approval by Lloyd's Register (hereinafter referred to as 'LR') of electrodes, wires, fluxes and other consumables intended for use in the welding of the following types of materials:

(a) Steel of various grades as represented by Grade A through to Grade FH69, *see* Sections 3 to 7.
(b) A wide range of low-temperature service steels, *see* Sections 3 to 7.
(c) Stainless steels including nitrogen strengthened grades and some of the duplex varieties, *see* Section 8.
(d) Aluminium alloys, *see* Section 9.

1.1.2 For this purpose, welding, consumables are categorised and subject to the special requirements of different Sections of this Chapter.

(a) Covered electrodes for manual welding and gravity welding.
(b) Combinations of wire and flux for automatic submerged-arc welding.
(c) Combinations of wire and gas for gas metal-arc welding and wires for self-shielding welding.
(d) Combinations for electro-slag and electro-gas welding.
(e) Combinations with temporary backing materials for one-side welding.
(f) Consumables for welding austenitic and duplex stainless steels.
(g) Combinations for welding aluminium.

1.2 Grading

1.2.1 Consumables for welding structural steels are graded into ten strength levels, and each of these is further subdivided into several levels in respect of notch toughness. The five basic levels of toughness are indicated by a number (1 to 5). Normal tensile strength is indicated by 'N'. Higher tensile strength is indicated by 'Y', and if the yield strength is higher than 375 N/mm^2 the Y is followed by a number (40 to 69), as shown in Table 11.1.1.

1.2.2 In addition to the grade, consumables are also allocated a suffix indicating the welding technique used. These are defined in the context of the following Sections of this Chapter.

1.2.3 Consumables for structural and low temperature service steels may be controlled low hydrogen and approved as such. Grade marking H15, H10 or H5 will be applied, as appropriate.

1.2.4 For joining higher strength steels, approval granted for 1Y consumables will be limited to maximum material thickness of 25 mm.

1.2.5 Test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grade.

1.2.6 Further details of grading are given in subsequent Sections of this Chapter.

1.3 Manufacture

1.3.1 The manufacturer's plant and method of production of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.4 Approval procedures

1.4.1 Welding consumables will be approved subject to a satisfactory inspection of the works by the Surveyor for compliance with the test requirements detailed in subsequent Sections in this Chapter.

1.4.2 The test assemblies are to be prepared under the supervision of the Surveyor, and using samples selected by him. All tests are to be carried out in his presence.

1.4.3 For Charpy V-notch tests, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Sections in this Chapter. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value.

1.4.4 Where chemical analysis is required for approval, the results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades

Consumable grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (Ch 3,2 and Ch 3,3)				
1N	A	***AH27S***	—	—
2N	B, D	***DH27S***	—	—
3N	E	***EH27S***	—	—
1Y	A	***AH27S***	***AH32***	***AH36***
2Y	B, D	***DH27S***	***DH32***	***DH36***
3Y	E	***EH27S***	***EH32***	***EH36***
4Y	—	***FH27S***	***FH32***	***FH36***
2Y40	***AH32***	***AH36***	***AH40***	—
2Y40	***DH32***	***DH36***	***DH40***	—
3Y40	***EH32***	***EH36***	***EH40***	—
4Y40	***FH32***	***FH36***	***FH40***	—
5Y40	***FH32***	***FH36***	***FH40***	—
3Y47	—	—	***EH40***	***EH47***
2. High Strength Steels (Ch 3,10) *see* Note 3				
3Y42	***AH36***	***AH40***	AH42	—
3Y42	***DH36***	***DH40***	DH42	—
4Y42	***EH36***	***EH40***	EH42	—
5Y42	***FH36***	***FH40***	FH42	—
3Y46	***AH40***	AH42	AH46	—
3Y46	***DH40***	DH42	DH46	—
4Y46	***EH40***	EH42	EH46	—
5Y46	***FH40***	FH42	FH46	—
3Y50	AH42	AH46	AH50	—
3Y50	DH42	DH46	DH50	—
4Y50	EH42	EH46	EH50	—
5Y50	FH42	FH46	FH50	—
3Y55	AH50	AH55	—	—
3Y55	DH50	DH55	—	—
4Y55	EH50	EH55	—	—
5Y55	FH50	FH55	—	—
3Y62	AH55	AH62	—	—
3Y62	DH55	DH62	—	—
4Y62	EH55	EH62	—	—
5Y62	FH55	FH62	—	—
3Y69	AH62	AH69	—	—
3Y69	DH62	DH69	—	—
4Y69	EH62	EH69	—	—
5Y69	FH62	FH69	—	—
3. Ferritic Low Temperature Service Steels (Ch 3,6)				
$1\frac{1}{2}$ Ni	$1\frac{1}{2}$ Ni	—	—	—
$3\frac{1}{2}$ Ni	$3\frac{1}{2}$ Ni	—	—	—
5 Ni	5 Ni	—	—	—
9 Ni	9 Ni	—	—	—

NOTES
1. Steel grades shown in bold italic type include the equivalent (LT-xxxx) low temperature service grades referenced in Ch 3,6.
2. The Table applies to the multi-run welding techniques (i.e. m, S, M).
3. Approval of consumables intended for welding high strength steels in Ch 3,10 also includes the standard ship steel grades as shown in bold italic type and equivalent low temperature service steel grades referenced in Ch 3,6.

1.4.5 LR may require, in any particular case, such additional tests or requirements as may be necessary.

1.4.6 A *List of Approved Welding Consumables* is published by LR.

1.4.7 LR is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval. Sufficient detail is to be provided to determine the need for further testing to maintain the approval.

1.4.8 Consideration will be given to alternative procedures for approval in the case of manufacturers producing consumables under the control of another manufacturer or plant already having approval of one or more products.

1.5 Annual inspection and tests

1.5.1 All establishments where approved welding consumables are manufactured, and the associated quality control procedures, are to be subjected to annual inspection. On these occasions, samples of the approved consumables are to be selected by the Surveyor and subjected to the tests detailed in subsequent Sections in this Chapter. These are to be completed and reported before the end of the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. For upgrading in connection with impact properties, and uprating in connection with tensile properties, tests from butt weld assemblies will be required in addition to the normal annual approval tests. For upgrading in connection with hydrogen testing, specific tests will be required in accordance with ISO 3690. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

1.7 Manufacturers' Quality Assurance Systems

1.7.1 As an alternative to 1.5, manufacturers may seek maintenance of approval based on acceptance by LR of their 'in house' quality assurance system, and by regular audit of that system carried out in accordance with procedures approved by LR.

1.8 Certification

1.8.1 Each carton or package of approved consumables is to contain a certificate from the manufacturer, generally in accordance with the following: 'The <*insert name of manufacturer*> company certifies that the composition and quality of these consumables conform with those of the consumables used in making the test pieces submitted to and approved by the approval bodies nominated on the label of this package.'

Section 2
Mechanical testing procedures

2.1 Dimensions of test specimens

2.1.1 Dimensions of test pieces for deposited metal tensile tests, butt weld tensile tests, bend tests and Charpy V-notch impact test are to machined to the dimensions and tolerances detailed in Chapter 2.

2.2 Testing procedures

2.2.1 The procedures used for all tensile and impact tests are to comply with the requirements of Chapter 2.

2.2.2 Butt weld bend test specimens are to be tested at ambient temperature and are to be bent through an angle of 120° over a former having a diameter which relates to the thickness of the test specimen as detailed in subsequent Sections. For each pair of bend test specimens, one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

2.2.3 Macro examinations are to be carried out on polished and etched specimens at a maximum magnification not exceeding x10. The examination is to ensure complete fusion, inter-run penetration and freedom of defects.

2.3 Re-testing procedures

2.3.1 Re-testing procedures are to comply with Ch 2,1.4.

Section 3
Electrodes for manual and gravity welding

3.1 General

3.1.1 Dependent on the results of the mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

3.1.2 Approval of an electrode will be given in conjunction with a welding technique indicated by a suffix 'm' for manual welding, 'G' for gravity or contact electrode and 'p' for deep penetration electrode.

3.1.3 If the electrodes are in compliance with the requirements of the hydrogen test given in 3.4, a suffix 'H15' or 'H10' or 'H5' will be added to the grade mark. Table 11.3.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

3.1.4 For each strength level, electrodes which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to 5Y40	H15
3Y47	H10
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
1½ Ni	H15
3½ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

3.1.5 Electrodes approved for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

3.1.6 Electrodes approved for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

3.1.7 Electrodes approved for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

3.1.8 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

3.1.9 Where an electrode is submitted only for approval for fillet welding and to which the butt weld test provided in 3.3 is not considered applicable, approval tests are to consist of the fillet weld tests as given in 3.5 and deposited metal tests with chemical analyses as given in 3.2.

3.2 Deposited metal test assemblies

3.2.1 The deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one with 4 mm diameter electrodes and the other with 8 mm diameter electrodes, or the largest size manufactured if this is less than 8 mm diameter. If an electrode is available in one diameter only, one test assembly is sufficient. Any of the grades of steel in Table 11.1.1 may be used for the preparation of these assemblies, up to a strength level which is not more than two levels above that for which approval is sought.

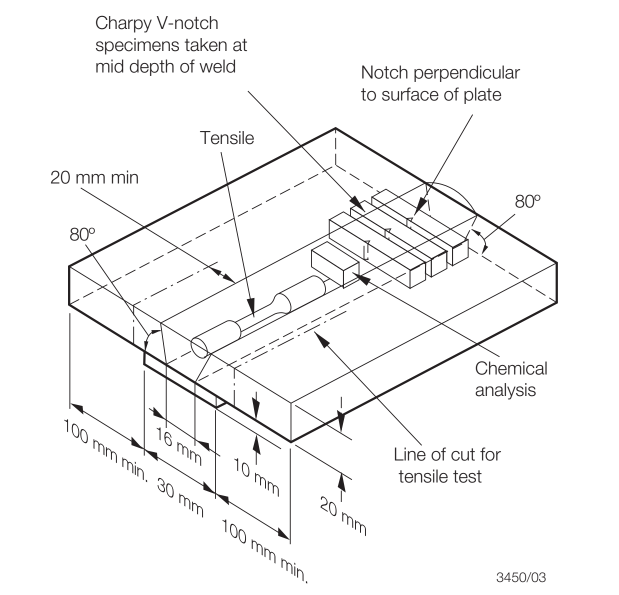


Fig. 11.3.1 Deposited metal test assembly

3.2.2 For Y47 grades, as an alternative to Fig. 11.3.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

3.2.3 The weld metal is to be deposited in single- or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code ‘sr’ will be added to the approval grading.

3.2.4 The chemical analysis of the deposited weld metal in each deposited metal test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

3.2.5 One tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.3.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld, with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

3.2.6 The results of all tests are to comply with the requirements of Table 11.3.2 as appropriate.

3.3 Butt weld test assemblies

3.3.1 Butt weld assemblies, as shown in Fig. 11.3.2, are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode is recommended by the manufacturer. In the case of electrodes for normal strength and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), electrodes satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. In all other cases, approval for the horizontal-vertical position will require a butt weld to be made in that position and fully tested.

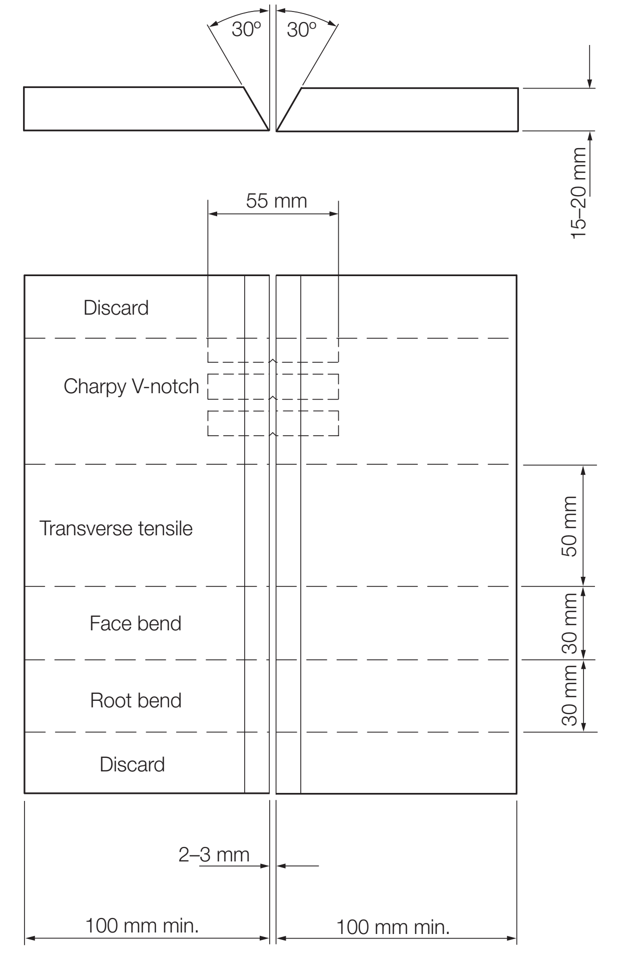


Fig. 11.3.2 Butt weld test assembly

3.3.2 For Y47 grades, as an alternative to Fig. 11.3.2 the thickness of the plate used for the test assembly may be taken as 50 mm.

3.3.3 Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2 (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	47
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	47
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	47
3Y47	460	570 – 720	19	–20	53
3Y40	400	510 – 690	22	–20	47
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	47
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 – 690	22	–60	47
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
$1^1/_2$ Ni	375	460	22	–80	34
$3^1/_2$ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTES
1. Single values are the minimum requirements.
2. Energy values from individual impact test specimens are to comply with 1.4.3.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

3.3.4 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 5Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 3Y47 electrodes	EH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

3.3.5 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

3.3.6 The test assemblies are to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root gap 2 to 3 mm. The root face is to be 0 to 2 mm.

3.3.7 The following welding procedure is to be adopted in making the test assemblies:

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Downhand (b) (where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Horizontal-vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3,25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode being tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

3.3.8 For all assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

3.3.9 Normal welding practice is to be used and, between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code ‘sr’ will be added to the approval grading.

3.3.10 It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3.3.11 The test specimens as shown in Figs. 11.3.2 and 11.3.3 are to be prepared from each test assembly.

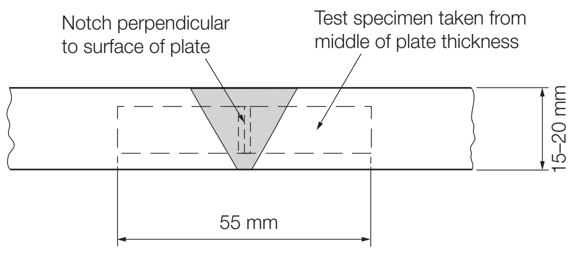


Fig. 11.3.3
Butt weld test assembly position of impact test specimens

3.3.12 The results of all tensile and impact tests are to comply with the requirements of Table 11.3.3 as appropriate. The position of fracture in the transverse tensile test is to be reported.

3.3.13 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defect exceeding 3 mm in dimensions can be seen on the outer surface.

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4. Where ISO 3690 is used as the testing method, three test specimens are to be prepared and tested, and all three hydrogen test results must be below the maximum value for the hydrogen mark required.

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.4. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested. Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in subsequent paragraphs of this sub-Section welded in the horizontal-vertical position.

3.5.2 For Y47 grades, as an alternative to Fig. 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Note 1) J minimum All positions (*see* Note 2)
1N, 2N, 3N	400	3	+20, 0, –20	47 (34)
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	47 (34)
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	47 (39)
3Y47	570 – 720	4	–20	53
3Y40	510	3	–20	47 (39)
3Y42	530 – 680	4	–20	47
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	47 (39)
4Y42	530 – 680	4	–40	47
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1$^1/_2$ Ni	490	3	–80	27
3$^1/_2$ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to welds made in the vertical position with upward progression.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (or Glycerine) (*See* Note)
H10	ISO 3690
H5	ISO 3690

NOTE
ISO method preferred.

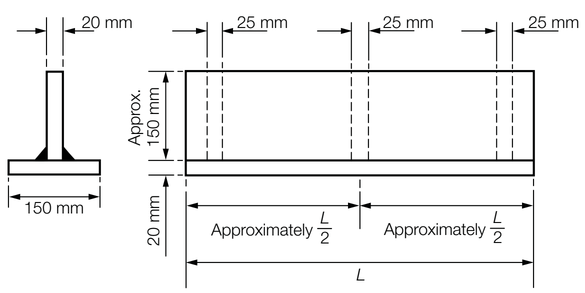


Fig. 11.3.4 Fillet weld test assembly

3.5.3 The electrode sizes to be used are the maximum and minimum diameters recommended by the manufacturer for fillet welding. The first side is to be welded using the maximum diameter. The second side is to be welded only after the assembly has been allowed to cool below 50°C using the minimum diameter. The size of these single run fillet welds will, in general, be determined by the electrode size and the welding current employed during testing and should represent the range of fillet weld bead sizes recommended by the manufacturer.

3.5.4 Each test assembly is to be sectioned to form three macro-sections, each about 25 mm thick. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions. Any undercut is not to exceed 0,5 mm in depth. Convexity or concavity of the profile is not to exceed one-tenth of the fillet bead throat dimension. All such observations are to be reported.

3.5.5 Hardness measurements are to be made on the central macro-section only, as shown in Fig. 11.3.5. The results are to be reported.

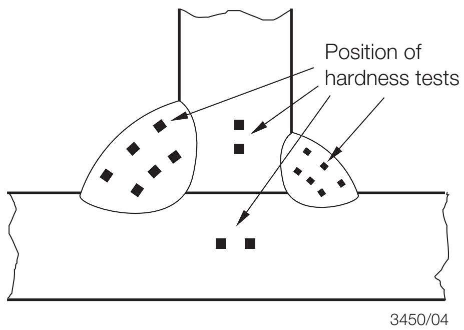


Fig. 11.3.5
Hardness tests for fillet weld test assembly

3.5.6 One of the remaining sections of the assembly is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld on the second side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined. They are to show satisfactory penetration, freedom from cracks and reasonable freedom from porosity and this should be reported.

3.6 Electrodes designed for deep penetration welding

3.6.1 Where an electrode is designed solely for the deep penetration welding of downhand butt joints and horizontal-vertical fillets in normal tensile strength steel, only the tests detailed in 3.7 and 3.8 are required for approval purposes.

3.6.2 Electrodes designed solely for the deep penetration welding technique will be approved as complying with Grade 1 requirements only and will be given the suffix ‘p’.

3.6.3 Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode, and the full series of tests in the downhand position is to be carried out, together with the deep penetration tests given in 3.7 and 3.8.

3.6.4 Where a manufacturer desires to demonstrate that an electrode, in addition to its use as a normal penetration electrode, also has deep penetrating properties when used for downhand butt welding and horizontal fillet welding, the additional tests given in 3.7 and 3.8 are to be carried out.

3.6.5 Electrodes approved for both normal and deep penetration welding will have the suffix ‘p’ added after the appropriate grade mark for normal penetration welding.

3.6.6 Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test assemblies in each case.

3.7 Deep penetration butt weld test assemblies

3.7.1 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. 11.3.6. Grade A steel is to be used for these test assemblies. The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm. The test assembly is to be welded using an 8 mm diameter electrode, or the largest diameter manufactured if this is less than 8 mm and the assembly is to be allowed to cool below 50°C between runs.

3.7.2 The test specimens as shown in Figs. 11.3.3 and 11.3.6 are to be prepared from each test assembly.

3.7.3 The results of tensile and impact tests are to comply with the requirements of Table 11.3.3 for Grade 1 electrodes. The position of fracture in the tensile test is to be reported. The bend test specimens are to be in accordance with 3.3.13.

3.7.4 The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and inter-penetration of the weld beads. At each cut in the test assembly, the joints are also to be examined to ensure that complete fusion has taken place.

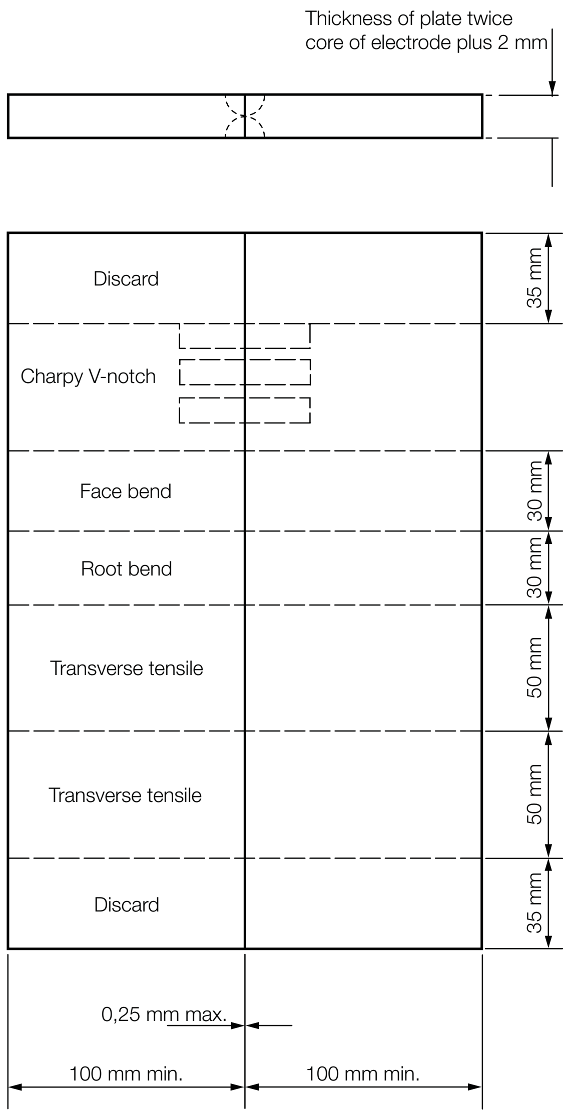


Fig. 11.3.6
Deep penetration butt weld test assembly

3.8 Deep penetration fillet weld test assemblies

3.8.1 A fillet weld assembly is to be prepared as shown in Fig. 11.3.7 with plates about 12,5 mm in thickness. The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is to be not more than 0,25 mm. Grade A steel is to be used for these test assemblies.

3.8.2 The fillet weld on one side of the assembly is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer, and the welding is to be carried out using normal welding practice except that the assembly is to be allowed to cool below 50°C between runs.

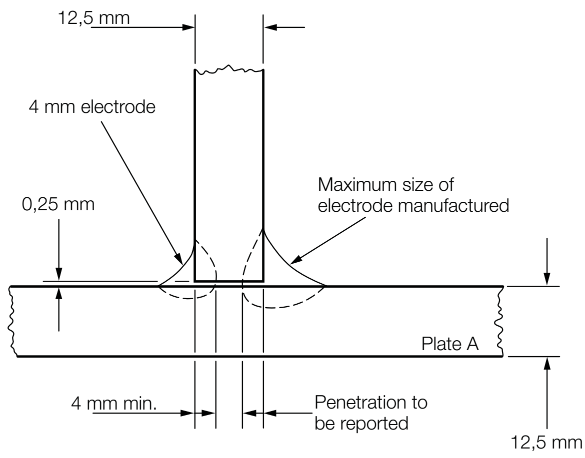


Fig. 11.3.7
Deep penetration fillet weld test assembly

3.8.3 The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds, and the joints are to be polished and etched. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of 4 mm (*see* Fig. 11.3.7) and the corresponding penetration of the fillet made with the maximum diameter of electrode manufactured is to be reported.

3.9 Electrodes designed for gravity or contact welding

3.9.1 Approval for welding using the gravity, 'G', technique is available for welding only normal strength and higher tensile steels up to and including Grade 36.

3.9.2 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, butt weld tests and, where appropriate, fillet weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

3.9.3 Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, butt weld and, where appropriate, fillet weld tests, using the gravity or other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

3.10 Annual tests

3.10.1 For normal penetration electrodes, the annual tests are to consist of two deposited metal test assemblies. These are to be prepared and tested in accordance with 3.2. If an electrode is available in one diameter only, one test assembly is sufficient.

3.10.2 Where an electrode is approved solely for deep penetration welding, the annual test is to consist of one butt welded test assembly. This is to be prepared and tested in accordance with 3.7.

3.10.3 Where an electrode is approved for both normal and deep penetration welding, annual tests as detailed in 3.10.1 and 3.10.2 are to be carried out.

3.10.4 Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer.

3.10.5 Where an electrode is approved for both manual and gravity welding, annual tests as detailed in 3.10.1 and 3.10.4 are to be carried out.

■ *Section 4* Wire-flux combinations for submerged-arc automatic welding

4.1 General

4.1.1 Wire-flux combinations for single and multiple electrode submerged-arc automatic welding, without the use of temporary backing, are divided into the following two categories:

- For use with the multi-run technique.
- For use with the two-run technique.

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

4.1.2 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

4.1.3 The suffixes T or M will be added after the grade mark to indicate approval for the two-run technique or, multi-run technique respectively.

4.1.4 Wire-flux combinations satisfying the requirements for multi-run or two-run techniques will also be approved for fillet welding in the downhand and horizontal-vertical position, subject to agreement by the manufacturer.

4.1.5 If the consumable combination is in compliance with the requirements of the hydrogen test given in 3.4, a suffix H15, H10 or H5 will be added to the grade. Table 11.4.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

4.1.6 For each strength level, wire-flux combinations which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to 5Y40	H15	NR
3Y47	H10	H15
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
$1^1/2$ Ni	H15	NR
$3^1/2$ Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

NOTES
1. NR – Not required. Approval can be obtained when requested.
2. Assumes use of an austenitic, non-transformable, filler material.

4.1.7 Wire-flux combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

4.1.8 Wire-flux combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

4.1.9 Wire-flux combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

4.1.10 Wire-flux combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 4.5.1.

4.1.11 The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

4.1.12 Wire-flux combinations for multiple electrode submerged-arc welding will be subject to separate approval tests. These are to be carried out generally in accordance with the requirements of this Section.

4.1.13 Wire-flux combinations are not naturally low hydrogen in character, but for the lower strength grades of steel low hydrogen testing is not normally a requirement for approval. With higher strength steels it is more important and Table 11.4.1 shows the mandatory minimum low hydrogen status required for approval of wire-flux combinations.

4.2 Approval tests for multi-run technique

4.2.1 Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

4.3 Deposited metal test assemblies (multi-run technique)

4.3.1 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1, using any of the grades of steel in Table 11.1.1 up to a strength level which is not more than two levels above that for which approval is sought.

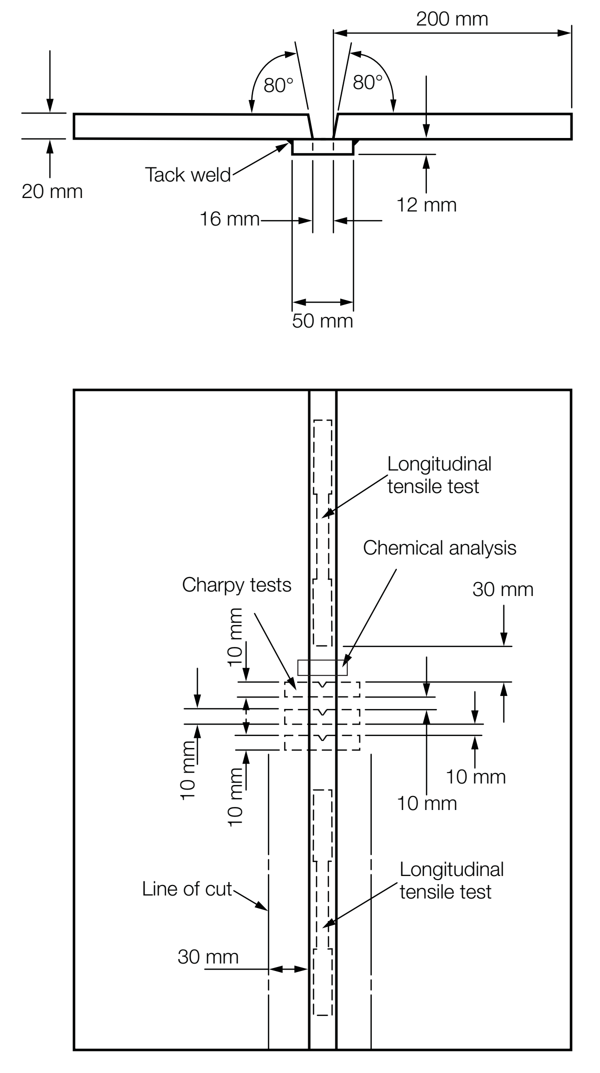


Fig. 11.4.1 Deposited metal test assembly

4.3.2 For Y47 grades, as an alternative to Fig. 11.4.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

4.3.3 The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges.

4.3.4 Welding is to be in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

4.3.5 The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

4.3.6 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.3.7 Two longitudinal tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.4.1. Care is to be taken that the axes of the tensile test specimens coincide with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

4.3.8 In those cases where two-run technique approval is also sought, only one longitudinal tensile specimen need be prepared and tested from this assembly.

4.3.9 The results of all tests are to comply with the requirements of Table 11.4.2, as appropriate.

4.4 Butt weld test assemblies (multi-run technique)

4.4.1 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2.

Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	39
3Y47	460	570 – 720	19	–20	53
3Y40	400	510 – 690	22	–20	39
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	39
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 –690	22	–60	39
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1½ Ni	375	460	22	–80	34
3½ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTE
Energy values from individual impact test specimens are to comply with 1.4.3.

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40
Grade 3Y40 wire-flux combinations	AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations	AH40, DH40, EH40 or FH40
Grade 5Y40 wire-flux combinations	AH40, DH40 EH40, FH4
Grade 3Y47 wire-flux combinations	EH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.4.3 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

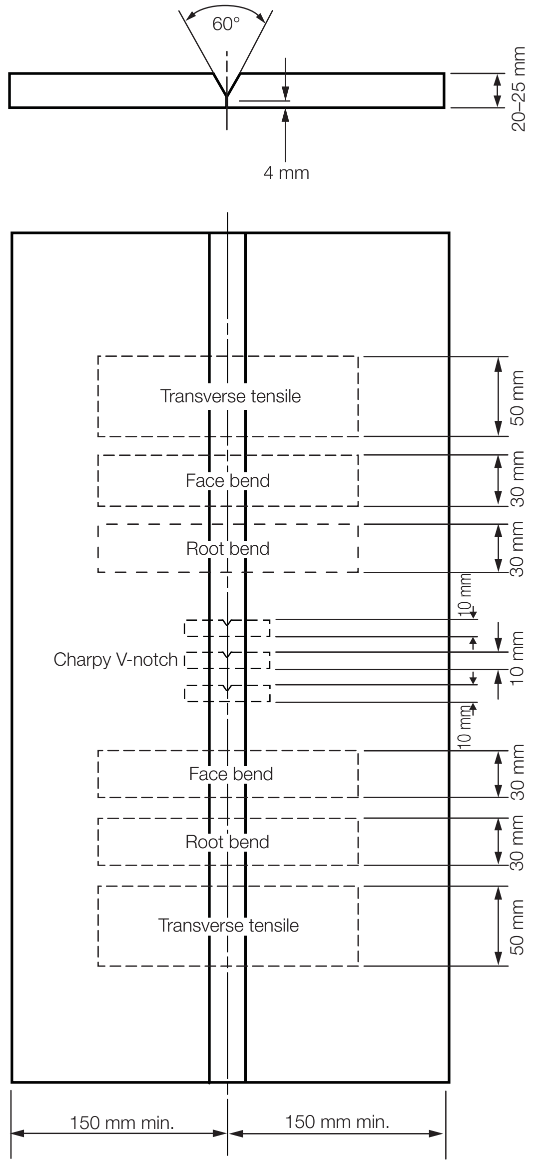


Fig. 11.4.2
Butt weld test assembly (multi-run technique)

4.4.4 The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from bevelled edges.

4.4.5 Welding is to be carried out in the downhand position by the multi-run technique, and the welding conditions are to be the same as those adopted for the deposited metal test assembly. The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

4.4.6 It is recommended that the welded assembly be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.4.7 The test specimens as shown in Fig. 11.3.3 and Fig. 11.4.2 are to be prepared from each test assembly.

4.4.8 The results of all tensile and impact tests are to comply with the requirements of Table 11.4.3, as appropriate. The position of fracture of the transverse tensile test is to be reported.

4.4.9 The bend test specimens can be considered as complying with the requirements if, after bending, no cracks or other open defects exceeding 3 mm in dimension can be seen on the outer surface.

4.5 Approval tests for two-run technique

4.5.1 Where approval for use with the two-run technique is requested, two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

4.5.2 Two welded assemblies are to be made from a pair of plates of matching thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

4.6 Butt weld test assemblies (two-run technique)

4.6.1 The grade of steel used for the preparation of the test assemblies is not to be of any higher grade (impact toughness) than that for which approval is required. The chemical composition, including the content of grain refining elements, and the strength properties of the plates used, are to be reported.

4.6.2 The maximum diameter of wire and the edge preparation to be used are to be in accordance with Table 11.4.4. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm.

4.6.3 Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

4.6.4 It is recommended that the butt weld assemblies be subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

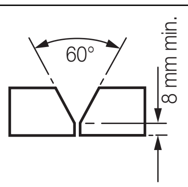
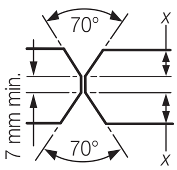
4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly, except as detailed in 4.6.8. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
1N, 2N, 3N	400	3	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	39
3Y47	570 – 720	4	–20	53
3Y40	510	3	–20	39
3Y42	530 – 680	4	–20	47 (41)
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	39
4Y42	530 – 680	4	–40	47 (41)
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1½ Ni	490	3	–80	27
3½ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to two-run technique impact test specimens.

Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	Recommended diameter	Maximum diameter of wire mm
12,5		5
20–25		6
35–40		7

4.6.6 The results of transverse tensile and impact tests are to comply with the requirements of Table 11.4.3 as appropriate. The position of fracture of the transverse tensile tests is to be reported.

4.6.7 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defects exceeding 3 mm in dimensions can be seen on the outer surface. One of the specimens from each assembly is to be tested with the side first welded in tension, and the second specimen with the other side in tension.

4.6.8 The longitudinal tensile specimen shown in Fig. 11.4.3 is to be prepared from the thicker assembly, even in those cases where multi-run technique approval is also sought. This test specimen is to be machined to the dimensions shown in Ch 11,2.1.1, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen may be given a hydrogen release treatment in accordance with 2.1.1. The results of this test are to comply with the requirements of Table 11.4.2.

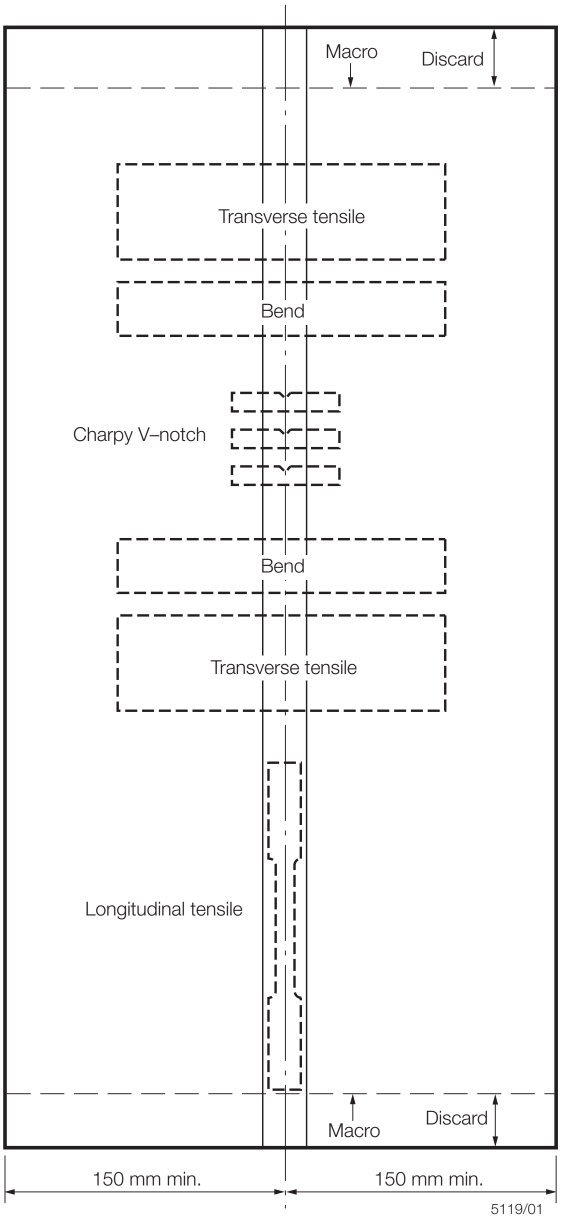


Fig. 11.4.3
Butt weld test assembly (two-run technique)

4.6.9 The chemical analysis of the weld metal of the second run in each assembly is to be determined and reported. This is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

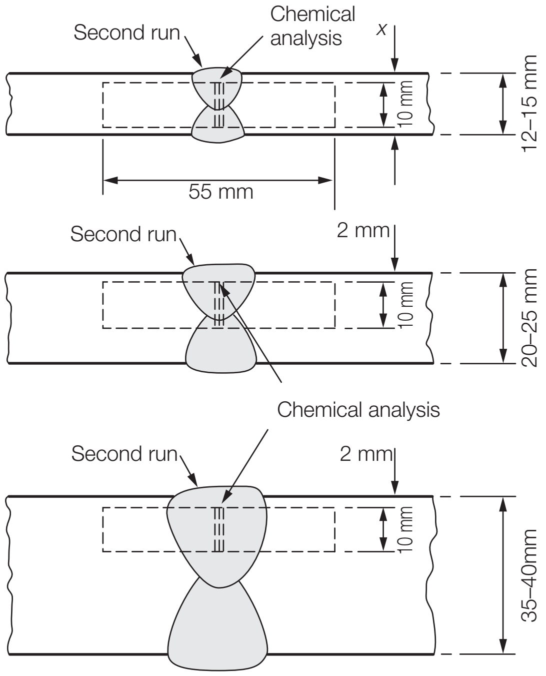


Fig. 11.4.4
Butt weld test assembly (two-run technique): position of impact test specimens

4.7 Annual tests

4.7.1 Annual tests are to consist of at least the following:

(a) For wire-flux combinations approved for the multi-run technique, one deposited metal test assembly.

(b) For wire-flux combinations approved for the two-run technique, one butt weld test assembly using plate material 20 to 25 mm in thickness. For Y47 the thickness of plate material may be taken as 50 mm.

4.7.2 The deposited metal assemblies are to be prepared and tested in accordance with 4.3, except that only one longitudinal tensile, three impact test specimens and a chemical analysis are required.

4.7.3 The butt weld test assemblies are to be prepared and tested in accordance with 4.6, except that only one transverse tensile, two bend, three impact test specimens and a chemical analysis are required. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

4.7.4 Where a wire-flux combination is approved for welding a range of steels with different specified minimum strength levels, steel of the highest strength approved is to be used for the preparation of the butt weld assembly required by 4.7.1(b).

Section 5
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

5.1.1 Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:
(a) For use in manual multi-run welding with the inert gas tungsten arc welding process (GTAW).
(b) For use in semi-automatic multi-run metal arc welding.
(c) For use in single electrode multi-run automatic metal arc and GTAW welding.
(d) For use in single electrode two-run automatic metal arc and GTAW welding.

5.1.2 The term 'manual', is used to describe the technique where the gas-shielded tungsten arc torch is held in one hand and the filler is added separately by the other hand.

5.1.3 The term 'semi-automatic' is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

5.1.4 In the GTAW process, 'automatic' refers to the fully mechanised control and application of both torch and separate filler wire.

5.1.5 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

5.1.6 A suffix S will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

5.1.7 For wires intended for automatic welding, the suffixes T or M will be added after the grade mark to indicate approval for two-run or multi-run welding techniques, respectively.

5.1.8 For wires intended for both semi-automatic and automatic welding, the suffices will be added in combination.

5.1.9 Solid wire-gas combinations are considered naturally low hydrogen in character and qualify for 'H15' approval without testing. This is not so for cored wires and continuous coated wires which must be tested if there is a need for low hydrogen approval. For the lower strength grades of steel, low hydrogen testing is not normally a requirement for approval. With higher strength steels, it is more important and Table 11.5.1 shows the mandatory minimum low hydrogen status required for approval of wire-gas combinations.

5.1.10 The testing methods to be used for low hydrogen approval are to be in accordance with 3.4, modified to use the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weld deposit weight per sample similar to that deposited when using manual electrodes.

5.1.11 Where applicable, the approved combination will name either the specific gas composition or its trade name, but in either case the composition of the shielding gas is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests. However a wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (see Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
3Y47	H10	H10	H10
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni	NR (see Note 3)	NR	NR
9 Ni	NR (see Note 3)	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

5.1.12 Wires and wire-gas combinations for multiple electrode automatic welding will be subject to separate approval tests. Any proposals are to be submitted for consideration.

5.1.13 Wires and wire-gas combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

5.1.14 Wires and wire-gas combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

5.1.15 Wires and wire-gas combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

5.1.16 Wires and wire-gas combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 5.4.1.

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.1 Approval tests for manual (GTAW) and semi-automatic multi-run welding are to be carried out generally in accordance with the requirements of Section 3, except as required by 5.2, using the respective technique for the preparation of all test assemblies.

5.2.2 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one using the smallest diameter, and the other using the largest diameter of wire for which approval is required. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

5.2.3 For Y47 grades, as an alternative to Figs. 11.3.1 to 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.2.4 The weld metal is to be deposited according to the practice recommended by the manufacturer, and the thickness of each layer of weld metal is to be between 2 mm and 6 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.2.5 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.6 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position. In all other cases, approval in the horizontal-vertical position will require a butt weld to be made in that position and be fully tested.

5.2.7 The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

5.2.8 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using, if possible, wires of different diameter from those required by 5.2.7. If only one wire diameter is to be approved, this second downhand butt weld should be made using either larger or smaller beads than the first assembly.

5.2.9 The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

5.2.10 Fillet weld test assemblies as detailed in 3.5 are to be prepared, examined and tested.

5.2.11 Low hydrogen approval tests are to be carried out if required by 5.1.9.

5.2.12 Test specimens from each assembly are to be prepared and tested in accordance with the requirements of 3.2 and 3.3.

5.3 Approval tests for multi-run automatic welding

5.3.1 Approval tests for multi-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.3, using the multi-run automatic welding technique for the preparation of all test assemblies.

5.3.2 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1. Welding is to be as detailed in 4.3.4, except that the thickness of each layer is to be not less than 3 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.3.3 For Y47 grades, as an alternative to Figs. 11.4.1 and 11.4.2, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.3.4 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2 for each welding position to be approved for the automatic multi-run technique.

5.3.5 Test specimens from each test assembly are to be prepared and tested in accordance with the requirements of Section 4 for multi-run submerged-arc automatic welding.

5.3.6 Low hydrogen approval tests are to be made if required by 5.1.9.

5.3.7 At the discretion of LR, wires approved for semi-automatic welding in the downhand position may also be approved without additional tests, for use in multi-run automatic welding.

5.4 Approval tests for two-run automatic welding

5.4.1 Approval tests for two-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.4, using the two-run automatic welding technique for the preparation of all test assemblies. Two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

5.4.2 Two butt weld test assemblies are to be prepared generally as detailed in 4.5 and 4.6 using plates 12 to 15 mm and 20 to 25 mm in thickness.

5.4.3 If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

5.4.4 The edge preparation of the test assemblies is to be as shown in Fig. 11.5.1. Small deviations in edge preparation may be allowed, if these form part of the consumable manufacturer's recommendations. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information.

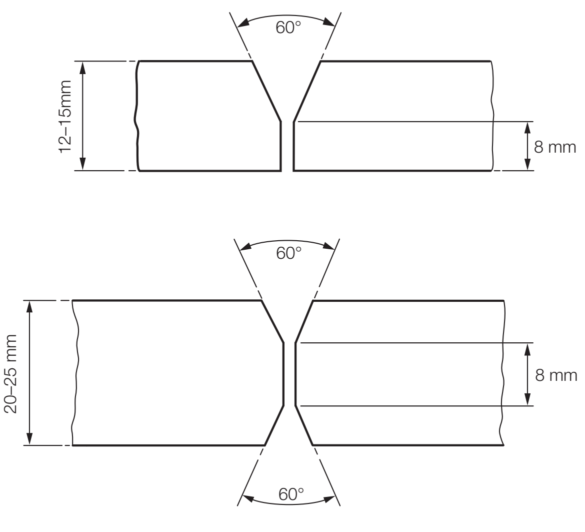


Fig. 11.5.1
Normal edge preparation for two-run butt weld test assemblies

5.4.5 The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

5.4.6 Test specimens from each butt weld assembly are to be prepared and tested in accordance with the requirements of Section 4 for two-run submerged-arc automatic welding.

5.4.7 The weld metal chemical analysis is to be reported as in 4.6.9. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.5 Annual tests

5.5.1 Annual tests are to consist of at least the following:

(a) Wires approved for manual welding or semi-automatic welding or either of these combined with approval for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.2 using a wire of diameter within the approved range.

(b) Wire approved for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.3 using a wire of diameter as stated in (a).

(c) Wires approved for two-run automatic welding:
one butt weld test assembly prepared in accordance with 5.4 using plates 20 to 25 mm in thickness or the maximum approved thickness. The diameter of wire used is to be reported.

■ *Section 6*
Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.1 The requirements for the approval of consumables used for electro-slag or electro-gas welding (including consumable nozzles, where applicable) are generally as detailed in Section 4 for two-run submerged-arc welding consumables, except as otherwise detailed in this Section.

6.1.2 For each grade, approval may be restricted for use with specific compositional types of steel. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 this will normally be in respect of the grain refining element content, and tests on niobium grain refined steel will normally qualify for use also on steels treated with aluminium or vanadium or combinations of these elements.

6.1.3 Superscript numbers are applied to the 'Y' of higher strength steel consumables, e.g. $2Y^1$, to indicate the type of parent steel for which approval is applicable as follows:

Y^1 approval Grade for higher strength steel is limited to parent steel which has been treated only with aluminium.

Y^2 approval Grade for higher strength steel is appropriate to niobium-treated steels, whether aluminium treated or not. It also covers steels treated only with aluminium.

6.1.4 Each strength level requires separate approval involving the welding and testing of two butt weld assemblies of different thickness. The greater thickness will determine the maximum approved thickness.

6.2 Butt weld test assemblies

6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 to 25 mm in thickness and the other with plates 35 to 40 mm in thickness. The steel used is not to be of any higher grade (impact toughness) than that for which approval is required. The limitations of 6.1.2 need to be considered in this Section. The chemical composition of the plate, including the content of grain refining elements, is to be reported.

6.2.2 The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer and are to be reported in detail. The manufacturer's maximum recommended gap between plates is to be used in making the test assemblies.

6.2.3 It is recommended that the assemblies are subjected to radiographic examination to identify any defects before the preparation of any test specimens.

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:

(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) Two macro-sections.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.2.5 The chemical analysis of the weld metal in each assembly is to be determined and reported. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

6.2.6 The results of all transverse tensile and impact tests are to comply with the requirements given in Table 11.4.3 as appropriate. The position of fracture of the transverse tensile test is to be reported. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

6.2.7 The results of all longitudinal tensile tests are to comply with the requirements of Table 11.4.2.

6.2.8 The bend test specimens are to be in accordance with 4.6.7 and Table 11.4.3. Each surface of the weld is to be tested Fension.

6.3 Annual tests

6.3.1 Annual tests are to consist of at least one butt weld test assembly using plate material 20 to 25 mm in thickness.

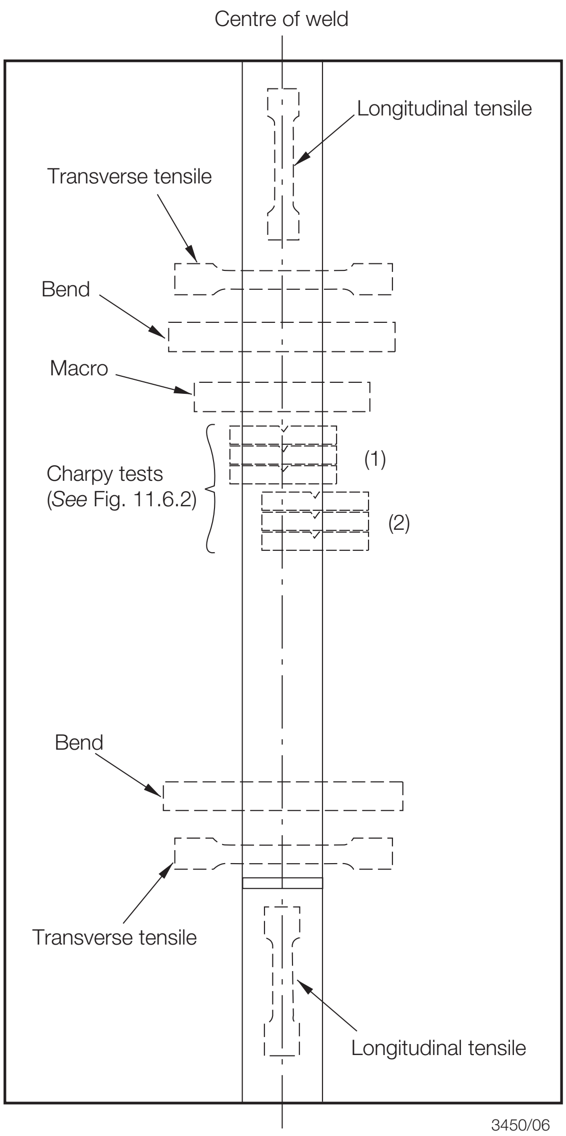
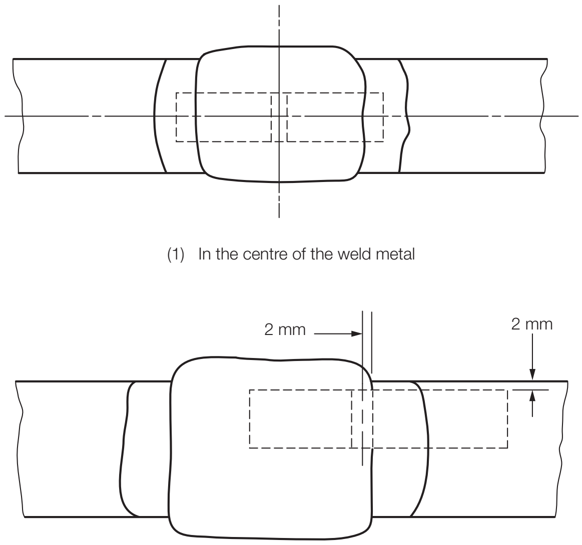


Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:

(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) Two sets of three Charpy V-notch impact tests; one set with the notch at the centre of the weld (Position (1) in Fig. 11.6.2), and one set with the notch in the weld metal 2 mm from the fusion line (Position (2) in Fig.11.6.2).
(e) Chemical analysis.
(f) One macro section.

6.3.3 Where a consumable or combination is approved for a range of steels with different specified minimum strength levels, steel of the highest strength level is to be used for the preparation for the assembly required by 6.3.1.



(1) In the centre of the weld metal

(2) In the weld metal, 2 mm from the fusion line

Fig. 11.6.2
Position of Charpy V-notch impact test specimens

■ *Section 7*

Consumables for use in one-side welding with temporary backing materials

7.1 General

7.1.1 The requirements for approval of combinations including temporary backing material, for use in one-side welding techniques, are dependent on the technique used and which basic technique it most closely follows. The following are provided for:

(a) Technique m – for manual electrode/backing combinations.
(b) Technique S – for wire-gas/backing combinations used with semi-automatic multi-run technique.
(c) Technique M – for wire-flux or wire-gas in combination with backing material (and maybe supplementary filler materials) used with an automatic multi-run technique.
(d) Technique A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

7.1.2 For technique m, S or M, a single butt weld is to be made in plate of 20–25 mm thickness. For technique A, two butt welds are to be made, one in plate of the maximum thickness recommended by the manufacturer, the other in plate of approximately half the thickness of the first. Usually this will involve thicknesses in the region of 35–40 mm and 20–25 mm respectively.

7.1.3 A wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide content is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

7.1.4 Any unrecognised techniques or unusual combinations will be considered for approval subject to a test programme to be agreed based on the details of the technique and combination which are to be submitted in advance.

7.1.5 Where low hydrogen approval is required either by Table 11.7.1 or by the manufacturer, it should be noted that this will generally be achieved through separate testing of:

(a) the backing material, and
(b) the welding electrode or combination of wire-flux or wire-gas.

7.1.6 The hydrogen potential of the backing material is to be determined using the modified Gayley-Wooding method which expresses the total hydrogen content as water by weight per cent. The qualifying levels are:

To qualify as:	H_20 g/100g sample
H15	0,5
H10	0,3
H5	0,2

7.1.7 The sampling and approval of the combinations without the backing are to follow the general requirements of Sections 3, 4 or 5, as appropriate.

7.1.8 Combinations approved with multi-run technique (m, S and M) for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

7.1.9 Combinations approved with multi-run technique (m, S and M) for strength levels Y40 to Y50, but excluding Y47, are also considered suitable for welding steels in two strength levels below that for which they have been approved.

7.1.10 Combinations approved with multi-run technique (m, S and M) for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

7.1.11 Combinations approved for the 'A' multi-run technique are not considered suitable for welding steels of any other strength level with that technique.

Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval grades	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
3Y47	H10	H10	H15
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni (*see* Note 3)	NR	NR	NR
9 Ni (*see* Note 3)	NR	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes the use of an austenitic, non-transformable, filler material.

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.1 For each position to be approved, one butt weld assembly is to be prepared using plates of 20–25 mm thickness as shown in Fig. 11.7.1. The grade of plate used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

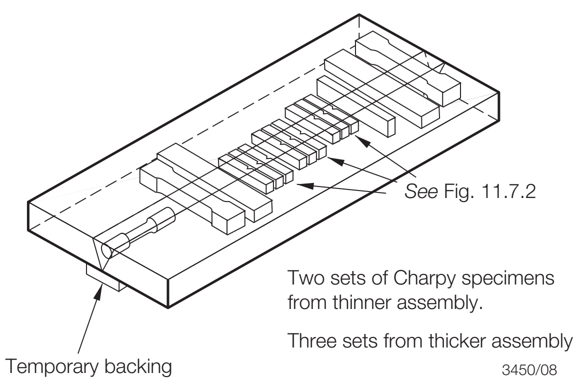


Fig. 11.7.1
Butt weld test assembly and specimens for all techniques

7.2.2 The thickness of test assembly is to be 50 mm for Y47 base material.

7.2.3 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers.

7.2.4 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):
(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens, one with the face in tension, the other with the root in tension.
(d) One macrosection.
(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a).

7.2.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements in Table 11.3.3 for m and S technique, and Table 11.4.3 for M technique. The position of fracture of the transverse tensile test is to be reported. The appearance of the bend test specimens is to be in accordance with 3.3.13.

7.2.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2.

7.2.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.2.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the upper and lower Charpy specimens of the downhand butt weld. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

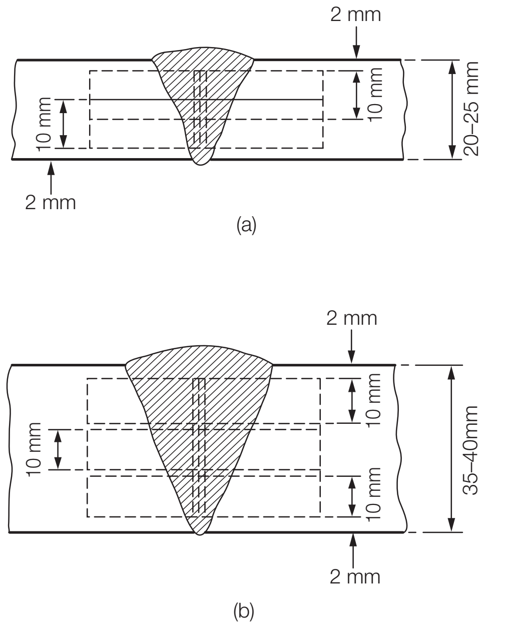


Fig. 11.7.2
Position of Charpy V-notch impact tests for one-side automatic welding

7.3 Approval tests for high heat input automatic (A) techniques

7.3.1 Two butt weld assemblies are to be prepared, usually one of 35–40 mm thickness, the other 20–25 mm, as shown in Fig. 11.7.1, noting that in the thinner assembly only two sets of Charpy specimens are required. The grade of plates used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.3.2 For Y47 grade, the thicker assembly is to be prepared from the maximum thickness for which approval is required, and the thinner assembly is to be prepared from 50 mm thickness. Where approval is required for 50 mm thickness, only one assembly from that thickness is required.

7.3.3 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommenda-tions, and are to be reported to LR.

7.3.4 Test specimens as follows are to be prepared as shown in Fig. 11.7.1 and Figs. 11.7.2(a) and (b):

(a) One longitudinal tensile test specimen (from centre of weld).
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) From assembly 20 to 25 mm thick, two sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(a).
(f) From assembly 35 to 40 mm thick, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b).
(g) From assembly of thickness 50 mm or more, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b). The second set positioned in the mid-thickness of test assembly.
The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.3.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements of Table 11.4.3. The appearance of the bend test specimens is to be in accordance with 3.3.13. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

7.3.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2, except that for Grades 1Y, 2Y and 3Y the tensile strength is to be not less than 490 N/mm^2.

7.3.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.3.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the thicker plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness.

7.4.2 The assembly is to be prepared and tested in accordance with 7.2 or 7.3, as appropriate, except that only the following tests are required:

(a) One longitudinal tensile test (from centre of weld).
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three impact tests taken from the root of the weld and the specimens notched in accordance with Fig. 11.7.2.
(e) Chemical analysis (one only).

■ *Section 8*
Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.1 Tests for the approval of consumables intended for welding the austenitic and duplex stainless steels detailed in Ch 3,7 are to be carried out generally in accordance with the Section (3, 4, 5, 6 or 7) relevant to the type of consumable or combination.

8.1.2 Approval will be indicated by the grade or grades of parent stainless steel for which the consumable or combination is approved.

8.1.3 Where a shielding gas is employed, separate approval will be required for each specific shielding gas composition.

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by 'SS/CMn' and 'Dup/CMn' respectively, however, no buttering of test assembly plates is allowed for these two approvals.

8.1.5 Separate approval will be given for welding chemical and cryogenic applications. For chemical use, evidence of relevant corrosion resistance will be required. Charpy impact toughness tests will be required for all uses, but for cryogenic use the Charpy impact toughness requirements are more severe.

8.1.6 The welding technique will be indicated in the approval grading by a letter:

- m – for manual SMAW or GTAW welding.
- S – for wire-gas combinations used with a semi-automatic multi-run technique.
- M – for wire-flux or wire-gas combinations used with an automatic multi-run technique.
- T – for wire-flux or wire-gas combinations used with an automatic two-run technique.
- A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

8.2 Deposited metal test assemblies

8.2.1 Where the relevant Section requires deposited metal assemblies to be made and tested, the plates used must be either of the type for which approval is required or of normal strength carbon, or carbon-manganese steel with the prepared edges built up with stainless steel weld metal and finished with a layer of weld metal from the consumable to be approved.

8.2.2 The chemical analysis of the deposited weld metal is to be reported, including all significant elements. The elements reported will be dependent on the type of stainless steel for which approval of the consumables is requested. Any unusual weld metal compositions will have to be justified in respect of the particular approval requested. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

8.2.3 The results of all tensile and notch impact tests are to comply with the requirements given in Table 11.8.1 as appropriate.

8.2.4 The ferrite content in the last weld run from each deposited metal assembly is to be determined by physical or metallographic means, and reported, indicating the method of determination.

Table 11.8.1 Requirements for deposited metal tests (manual, semi-automatic and automatic multi-run techniques)

Grade	0,2% proof stress N/mm^2 minimum	1% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on 50 mm % minimum	Charpy V-notch impact tests		
					Chemical test temperature °C	Cryogenic test temperature °C	Average energy *See* Note 1 J minimum
304L	270	310	500	25	–20	–196	29
304LN	305	345	530	22	–20	–196	29
316L	270	310	500	22	–20	–196	29
316LN	305	345	530	22	–20	–196	29
317L	305	345	530	22	–20	–196	29
317LN	340	380	570	22	–20	–196	29
321	290	330	550	22	–20	–196	29
347	290	330	550	22	–20	–196	29
S 31254	370	410	650	22	–20	–196	29
N 08904	270	310	500	22	–20	–196	29
SS/CMn	270	310	500	22	–20	–60	29
S 31260	485	525	690	20	–20	*see* Note 2	40
S 31803	450	490	620	25	–20		40
S 32550	550	590	760	15	–20		40
S 32750	550	590	800	15	–20		40
S 32760	550	590	750	25	–20		40
Dup/CMn	270	310	500	22	–20	*see* Note 2	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Approval for cryogenic applications is to be obtained at the procedure approval stage.

8.3 Butt weld test assemblies

8.3.1 Where the relevant Section requires butt weld assemblies to be made and tested, the plates used are to be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, provided the consumable is metallurgically compatible with the base material to be used, the prepared edges are to be built up with a layer of weld metal before final machining of the weld preparation.

8.3.2 The results of transverse tensile, notch impact and bend tests are to comply with the requirements of Table 11.8.2 as appropriate. The position of fracture is to be reported to LR.

8.3.3 The ferrite content at the centre of the weld metal in each butt weld assembly is to be determined by physical or metallographic means, and meet the requirements in Table 11.8.2. The method of determination is to be reported.

8.3.4 For austenitic and duplex stainless steel approvals (except for types 304L, 316L, 321 and 347), an appropriate sample from each butt weld assembly is to be submitted to the corrosion testing provided in ASTM G48, Method ‘C’. The results are to be reported so as to allow confirmation of the maximum acceptable pitting corrosion resistance temperature. This will be part of the approval grading and will be set at 5°C intervals. The minimum pitting corrosion temperature would not be expected to be less than 20°C.

8.4 Fillet weld test assemblies

8.4.1 Where the relevant Section requires fillet weld assemblies to be made and tested, the plates used must be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, the surfaces on which the fillet weld beads are to be deposited are to be cut back by machining and then built up to original dimensions with weld metal from the consumable to be approved.

8.4.2 The ferrite content at the centre of the weld metal in each fillet weld bead of each assembly is to be determined from the centre macro-section by physical or metallographic means, and reported. The method of determination is also to be reported to LR.

8.4.3 Where approval is sought for fillet welding only, corrosion testing is to be carried out in accordance with 8.3.4 from a sample taken from the deposited metal test assembly.

8.5 Annual tests

8.5.1 Annual tests are to be carried out as required by the relevant Section appropriate to the type of consumable and welding technique. The tests are to include a weld ferrite content in accordance with 8.2.4 or 8.3.3 as appropriate.

8.5.2 The results of all tests are to comply with the requirements given in Table 11.8.1 and Table 11.8.2 as appropriate.

Table 11.8.2 Requirements for butt weld tests (all techniques)

Grade	Tensile strength N/mm^2 minimum	Bend test ratio: $\frac{D}{t}$	Weld ferrite content %	Charpy V-notch impact tests		
				Chemical test temperature °C	Cryogenic test temperature °C	Average energy (*see* Note 1) J minimum
304L	500	3	4–12	–20	–196	27
304LN	530	3	4–12	–20	–196	27
316L	500	3	4–12	–20	–196	27
316LN	530	3	4–12	–20	–196	27
317L	530	3	4–12	–20	–196	27
317LN	570	3	4–12	–20	–196	27
321	550	3	4–12	–20	–196	27
347	550	3	4–12	–20	–196	27
S 31254	650	3	(*see* Note 2)	–20	–196	27
N 08904	500	3	(*see* Note 2)	–20	–196	27
SS/CMn	500	3	4–12	–20	–60	27
S 31260	690	4	35–65	–20	(*see* Note 3)	40
S 31803	620	3	35–65	–20		40
S 32550	760	6	35–65	–20		40
S 32750	800	6	35–65	–20		40
S 32760	750	6	35–65	–20		40
Dup/CMn	500	3	(*see* Note 2)	–20	(*see* Note 3)	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. To be reported for special consideration.
3. Approval for cryogenic applications is to be obtained at the procedure approval stage.

■ *Section 9*
Consumables for welding aluminium alloys

9.1 General

9.1.1 Tests for the approval of consumables intended for welding the aluminium alloys detailed in Chapter 8 are to be carried out generally in accordance with the requirements of Sections 1, 2 and 5, except as otherwise detailed in this Section.

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1. Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies, and may be of any temper listed in LR Rules.

Table 11.9.1 Requirements for butt weld tests

Consumable Approval Grade (*see* Note 1)	Base material used for the test	Tensile strength N/mm^2 minimum	Bend test ratio $\frac{D}{t}$
LR RA/LR WA	5754	190	3
LR RB/LR WB	5086	240	6
LR RC1/LR WC1	5083	275	6
LR RC2/LR WC2 (*see* Note 2)	5383 or 5456	290	6
LR RC3/LR WC3 (*see* Note 2)	5059	330	6
LR RD/LR WD (*see* Note 4)	6005A 6061 6082	170 170 170	6 6 6

NOTES
1. The prefixes 'R' and 'W' indicate 'rod' form (for Gas Tungsten Arc Welding (GTAW)) or 'wire' form (for Gas Metal Arc Welding (GMAW) and GTAW).
2. Approval of grade LR RC2/LR WC2 confers approval of 5383, 5456 and 5083 base material grade.
3. Approval of grade LR RC3/LR WC3 confers approval of 5059, 5383, 5456 and 5083 base material grades.
4. Approval of grade LR RD/LR WD confers approval of 6005A, 6061 and 6082 base material grades.

9.1.3 The welding technique will be indicated in the approval grading by a letter:

m – manual multi-run welding (GTAW),
S – semi-automatic multi-run welding (GMAW),
M – automatic multi-run welding (GTAW or GMAW),
T – automatic two-run welding (GMAW).

9.1.4 The compositions of the shielding gas and the filler/electrode wire are to be reported.

9.1.5 Approval granted using the multi-run technique for a specific filler/electrode wire with a gas in one of the groups listed in Table 11.9.2 will extend to any other gas compositions within that same group, provided that the gas composition is within the range recommended by the consumable manufacturer, subject to agreement with LR.

Table 11.9.2 Shielding gas compositions

Group	Gas composition (Vol. %) (*see* Note)	
	Helium	Argon
I-1	–	100
I-2	100	–
I-3	>0 ≤33	Remainder
I-4	>33 ≤66	Remainder
I-5	>66 ≤95	Remainder
S	Special gas	

NOTE
Gases of other composition (mixed gases) or special purity may be considered as special gases and will require separate approval tests.

9.1.6 Approval granted for the two-run technique will be for a specific shielding gas composition; additional tests may be required if a change in shielding gas composition is sought.

9.1.7 On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding except for the alloy Grades 6005A, 6061 and 6082. These are to be allowed to naturally age at ambient temperature for a period of 72 hours from the completion of welding, before testing is carried out. A second solution heat treatment is not permitted.

9.1.8 All butt test assemblies are to be subjected to both radiographic and visual examination and imperfections such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks assessed in accordance with Intermediate Level C of ISO 10042, aided where necessary by dye penetrant and ultrasonic examination.

9.1.9 Fillet weld test assemblies and macro-sections are to be visually examined for imperfections, such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks, in accordance with Intermediate Level C of ISO 10042, aided where necessary by radiographic and dye penetrant examination.

9.2 Approval tests for manual, semi-automatic and automatic multi-run techniques

9.2.1 Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies.

9.2.2 The welding parameters are to be within the range recommended by the manufacturer and are to be reported.

9.2.3 Welded assemblies are to be prepared and tested in accordance with 9.3, 9.4 and 9.5.

9.3 Deposited metal test assembly

9.3.1 One assembly is to be prepared in the downhand position as shown in Fig. 11.9.1.

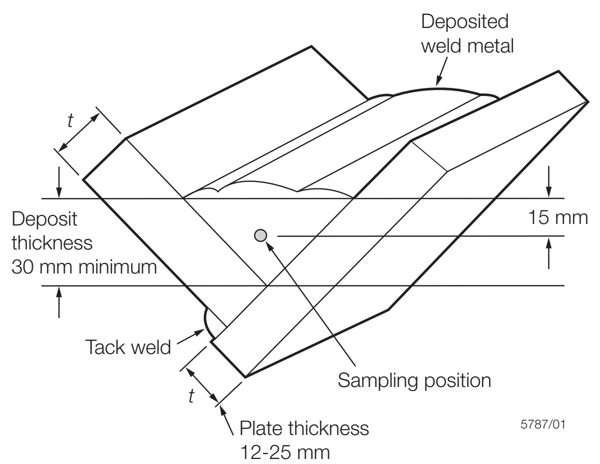


Fig. 11.9.1 Deposited metal test assembly

9.3.2 The chemical composition of the plate used for the assembly is to be compatible with the weld metal.

9.3.3 The thickness of the plate used, and the length of the assembly, are to be appropriate to the welding process. The plate thickness is to be not less than 12 mm.

9.3.4 For the approval of filler wire/gas and electrode wire/gas combinations for manual or semi-automatic welding by GTAW or GMAW, one test assembly is to be welded using any size of wire within the range for which approval is sought.

9.3.5 For automatic multi-run approval, one test assembly is to be welded by the respective process using the recommended diameter of wire.

9.3.6 The weld metal is to be deposited in multi-run layers in accordance with normal practice. The direction of deposition of each layer is to alternate from each end of the plate.

9.3.7 The deposited weld metal in the assembly is to be analysed and reported including the contents of all significant elements. The elements reported will be dependent on the type of aluminium alloy for which approval of the consumables is requested. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

9.4 Butt weld test assemblies

9.4.1 Plate of the corresponding type of aluminium alloy and of an appropriate thickness is to be used for the preparation of the test assemblies.

9.4.2 In order to ensure sound and representative welds, it is essential that test assemblies are cleaned and degreased prior to welding. Assemblies as shown in Fig. 11.9.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. Any wire diameter(s) to be approved may be used.

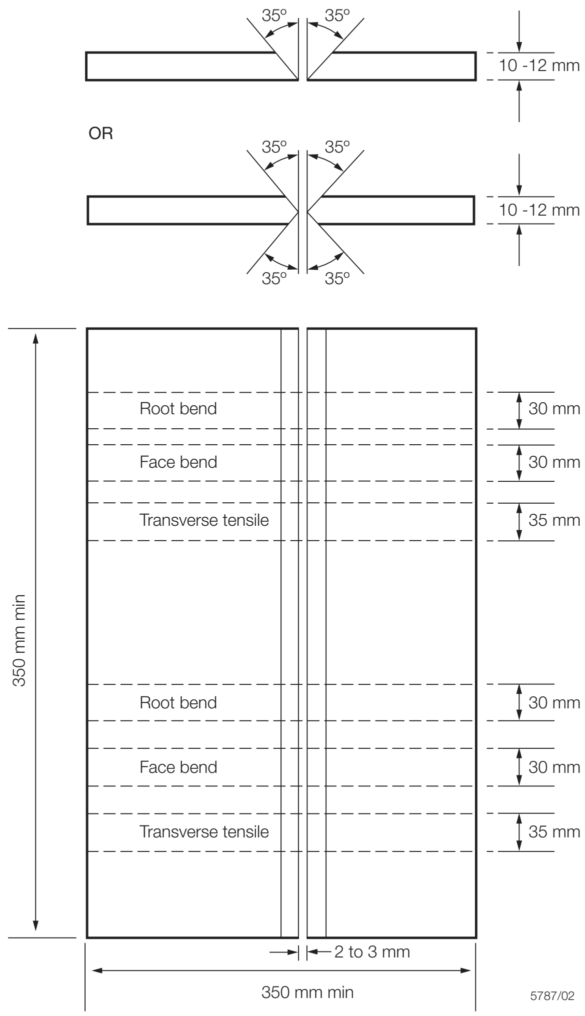


Fig. 11.9.2
Butt weld test assembly
(positional, multi-run technique)

9.4.3 One assembly, as shown in Fig. 11.9.3, is to be prepared for welding in the downhand position. The assembly is to be welded using, for the first run, wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved.

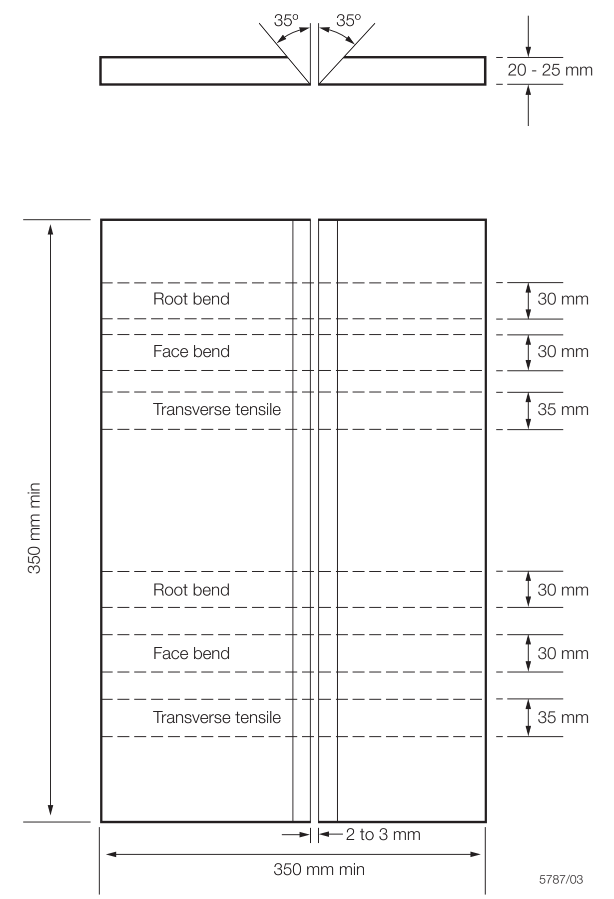


Fig. 11.9.3
Butt weld test assembly
(downhand, multi-run technique)

9.4.4 The welding conditions are to be in accordance with the recommendations of the manufacturer and are to be reported in detail.

9.4.5 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.4.6 The test specimens are to be taken from the welded assemblies as shown in Fig. 11.9.2 and Fig. 11.9.3. For each assembly they are to comprise:

- 2 transverse tensile specimens;
- 2 face bend specimens; and
- 2 root bend specimens.

9.4.7 All tensile test specimens are to have a tensile strength not less than the respective value shown in Table 11.9.1. The position of each fracture is to be reported.

9.4.8 The bend test specimens are to be bent around a former having a diameter not more than the number of times the thickness of the test specimen, as shown in Table 11.9.1, and can be considered as complying with the requirements if, after bending to an angle of not less than 180°, no crack or other open defect exceeding 3 mm in length can be seen on the outer surface. Flaws appearing at the corners of a test specimen may be ignored.

9.4.9 In order to obtain uniform bending of the bend test specimens, it is recommended that the wrap-around or guided bend test using a roller method is employed.

9.5 Fillet weld test assembly

9.5.1 When approval is being sought for both butt and fillet welding, one assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 When approval is being sought for fillet welding only, one assembly is to be prepared and welded in each position for which approval is sought, and tested as detailed in 9.5.1.

9.5.3 The results of examination of the macro-specimens and the fractured fillet welds are to be reported in accordance with 3.5.4 and 3.5.6. Imperfections are to be assessed in accordance with 9.1.9.

9.6 Approval tests for two-run technique

9.6.1 Two butt weld test assemblies are to be prepared using the following plate thicknesses:

(a) one with the maximum thickness for which approval is requested; and
(b) one with a thickness approximately one half to two thirds that of the maximum thickness.

9.7 Butt weld test assemblies (two-run technique)

9.7.1 The plates used are to be of the aluminium alloy appropriate to the approval required as shown in Table 11.9.1. The composition of the plate material is to be within the range specified for that alloy in Table 8.1.2 in Chapter 8 and is to be reported including all significant elements.

9.7.2 The wire diameter, edge preparation, welding current, arc voltage and travel speed are to be in accordance with the manufacturer's recommendations and are to be reported.

9.7.3 Each butt weld is to be made in two runs, one from each side. After completion of the first run, the assembly is to be left in still air until it has cooled to less than 50°C.

9.7.4 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.7.5 The test specimens as shown in Fig. 11.9.4 are to be prepared from each test assembly. The edges of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. Each cut in the assembly is also to be examined to confirm that complete fusion and penetration have been achieved.

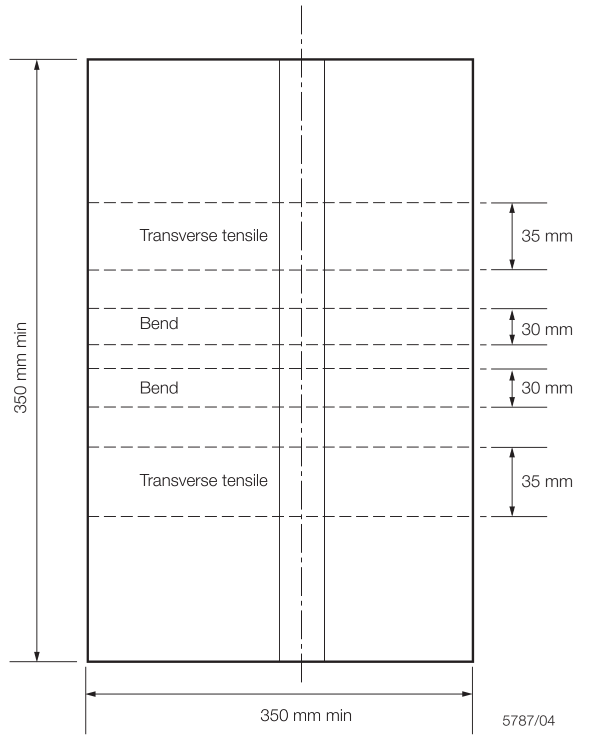


Fig. 11.9.4
Butt weld test assembly (two-run technique)

9.7.6 The results of the transverse tensile tests are to be as in 9.4.7 and of the bend tests as in 9.4.8. The position of the fracture in each transverse tensile specimen is to be reported.

9.8 Annual tests

9.8.1 Annual tests are to consist of the following:

(a) for combinations approved for the multi-run technique, one deposited metal assembly in 9.3 and one downhand butt assembly in 9.4;

(b) for combinations approved for the two-run technique, one butt weld assembly in plate material of thickness equal to one half to two thirds that of the maximum thickness approved.

9.8.2 For the automatic two-run technique, one butt weld assembly is to be prepared and tested in accordance with 9.7.

Welding Qualifications

■ *Section 1* General qualification requirements

1.1 General

1.1.1 This Section applies to all welding qualifications and tests required to be performed in the course of new construction, conversions, modifications or repairs made on ships, other marine structures and their associated pressure vessels, machinery and equipment.

1.1.2 These Rules also apply to all welding work related to other applications for which Lloyd's Register (hereinafter referred to as LR) have issued Rules or have an interest.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules. All deviations are to be recorded as non-compliances and brought to the attention of the Surveyor along with the corrective actions taken. Failure to do this is considered to render the welding tests as not complying with the Rules.

1.1.4 Welding tests are to be performed under survey at the manufacturer's works. Welding procedure qualification tests and welder qualifications tests are to be performed and approved prior to commencement of fabrication or construction.

1.1.5 Weld procedure tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.1.6 Welding tests that have previously been carried out may be considered for acceptance, provided that they have been supervised by an independent body acceptable to LR and the Surveyor is satisfied with the authenticity of such tests.

1.1.7 The responsibility for the performance of the weld tests rests with the manufacturer. Aspects of the welding tests, such as mechanical testing, non-destructive testing and heat treatment, may be subcontracted by the manufacturer provided that the subcontractor performs the work under the technical control and direction of the manufacturer, and this is agreed with the Surveyor prior to commencing the work.

1.1.8 In these Rules, the term 'manufacturer' is considered to include any firm or organisation that performs welding and is considered to be the shipbuilder, or construction firm, or fabricator, or material manufacturer.

1.2 Design

1.2.1 Welding procedure qualification tests are required to give assurance that construction welds made in accordance with the approved plans or the approved design have acceptable properties. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for a particular application.

1.2.2 The requirements relate to mechanical properties of the weld and heat affected zone, however, other tests may be required on certain materials, for example, corrosion or fatigue tests, in order to ensure suitability for the proposed application.

1.3 Materials

1.3.1 Materials used for testing are to be of the same grade, type and from the same manufacturing process as those to be used for construction, unless prior agreement is obtained from the Surveyor. Such agreements will only apply on a case-by-case basis.

1.3.2 All materials used for testing are to be suitably marked and identifiable to the original manufacturer's material certificate.

1.4 Performance of welding tests

1.4.1 All welding and subsequent testing is to be performed in accordance with the requirements of this Chapter.

1.4.2 The manufacturer is responsible for monitoring the tests and for recording all the welding variables as specified in 2.2 and for compiling all the non-destructive examination (NDE) reports and mechanical test records for submission to the Surveyor.

1.4.3 The laboratory or testing establishment used to perform the tests is to have the necessary equipment, maintained in good order and suitably calibrated. The Surveyor is to be satisfied that the laboratory personnel have the appropriate skills and are appropriately qualified in accordance with Ch 2,1.2.1.

■ *Section 2*

Welding procedure qualification tests for steels

2.1 General

2.1.1 The requirements of this Section relate to welding procedure test requirements of carbon, carbon-manganese steels and low alloys steels. Additional requirements for austenitic and austenitic/ferritic duplex stainless steels, aluminium and copper alloys are specified in Sections 3 and 4 respectively.

2.1.2 Prior to performing the welding procedure qualification test, the manufacturer is to present to the Surveyor a preliminary Welding Procedure Specification (pWPS) detailing the welding processes, positions, joint types, materials and heat treatments to be performed during the test. The pWPS is to be presented for information prior to commencing the test.

2.1.3 The type and extent of testing to be applied to each welding procedure test is to be in accordance with subsequent Sections of this Chapter.

2.1.4 For the welding procedure approval, the welding procedure qualification tests given in this Section are to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.2 Welding variables

2.2.1 In order that the conditions of the qualification test may be applied to production welding operations, the appropriate variables are to be recorded by the manufacturer during welding and testing from the following list:

(a) The unique qualification reference number and the date of welding;
(b) The material type, grade, product form, dimensions and identification;
(c) Welding process(es), including tack welds;
(d) Joint type, dimensions and surface condition;
(e) Welding position(s);
(f) Welding technique(s), weaving, multiple electrodes, etc;
(g) Welding consumables including fluxes, shielding gases, etc;
(h) Control of consumables, baking or drying conditions, etc;
(j) Welding parameters, current, voltages, travel speeds, etc;
(k) Number and sequence of weld runs;
(l) Backing materials including any backing gas;
(m) Preheats and interpass temperatures;
(n) Methods used for cleaning and inspection of root deposits;
(o) Post-weld heat treatment, temperature and cycle times;
(p) Special weld profiling requirements.

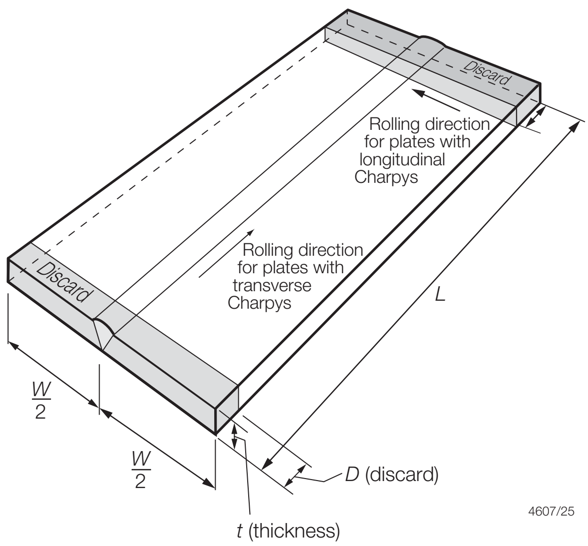
2.2.2 Other variables may need to be recorded depending on the particular welding process or application and are to be agreed with the Surveyor, for example the peak and base current and cycle times for pulse welding, electrode type and nozzle size for GTAW welding, etc.

2.3 Steel test assemblies

2.3.1 Tests are to be performed using the welding process and positions anticipated for actual construction. The weld test assemblies are to be representative of construction conditions and are to be welded in the same manner as intended for the actual production welds. Where pre-fabrication primers are used in the shipyard, these are to be included in the test assemblies.

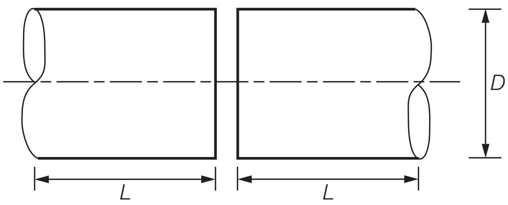
2.3.2 For plate tests, the direction of plate rolling relative to the weld direction is to be considered. Where the material used for the test requires longitudinal impact tests, the plate rolling direction is to be perpendicular to the weld direction and for material which requires impact testing in the transverse direction, the rolling direction is to be parallel to the weld direction. For weld tests intended for liquefied gas storage or cargo tanks and associated process pressure vessels, the direction of plate rolling is to be parallel to the weld direction in all cases.

2.3.3 Typical test assemblies are shown in Fig. 12.2.1(a) to (c). These are a minimum requirement to permit the removal of all the necessary mechanical test specimens. Where impact tests or other toughness tests are required, the total width is not to be less than 8 times the material thickness of the thicker material being joined.



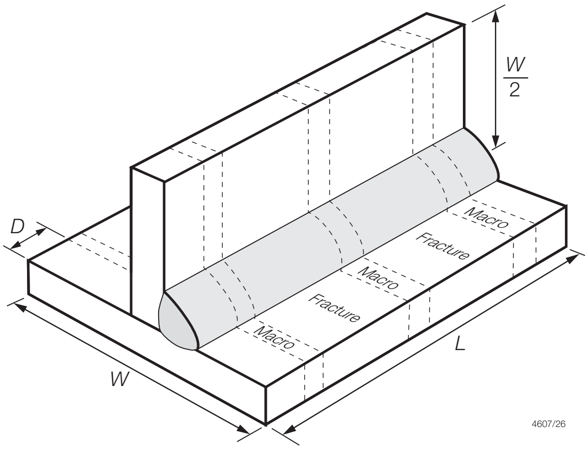
Welding Processes	L (min) mm	W (min) mm	D (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	400	75

Fig. 12.2.1(a) Butt weld test assembly in plate



L = 150 mm minimum
D = Outside diameter

Fig. 12.2.1(b) Butt weld test assembly in pipe



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	300	75

Fig. 12.2.1(c) Fillet weld test assembly in plate

2.3.4 Welding procedure test assemblies are to be welded separately from production welds and are to be marked with the unique test identification number. The individual pieces of the test assembly may be held together to maintain their relative joint conditions by means of suitable tack welds, clamps or strongbacks.

2.3.5 Welding of the test assemblies and testing of test specimens is to be monitored by the Surveyor.

2.3.6 The test assembly is to be placed in one of the welding positions shown in Fig. 12.2.2(a) to (d), as specified in the test Welding Procedure Specification (pWPS) and the specified level of preheat applied prior to the start of welding.

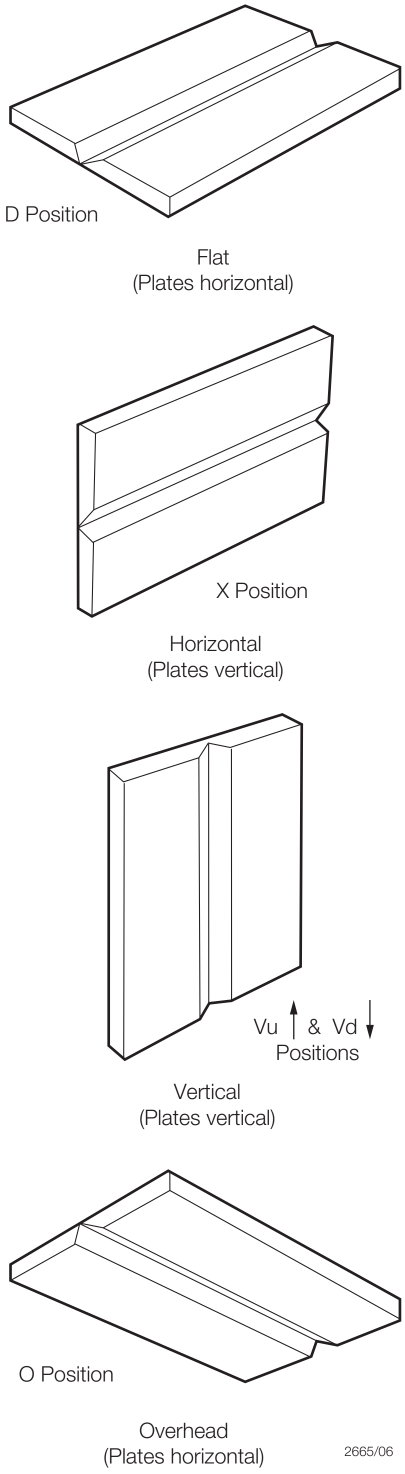
2.3.7 Designations for equivalent welding positions shown by different standards are shown in Table 12.2.1.

Table 12.2.1 Equivalent designations of welding positions

Weld position		Standard	
		ISO 6947	AWS
Plate butt welds			
Flat	D	PA	1G
Horizontal	X	PC	2G
Vertical, weld up	Vu	PF	3G
Vertical, weld down	Vd	PG	3G
Overhead	O	PE	4G
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF PG	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G
Plate fillet welds			
Flat	D	PA	1F
Horizontal	X	PB	2F
Vertical up	Vu	PF	3F
Vertical down	Vd	PG	3F
Overhead	O	PD	4F
Pipe fillet welds			
Flat, pipe rotated	D	PA	1FR
Horizontal, pipe fixed	X	PB	2F
Horizontal, pipe rotated	D	PB	2FR
Overhead, pipe fixed	O	PD	4F
Multiple, pipe fixed	D+Vu+O D+Vd+O	PF PG	5F

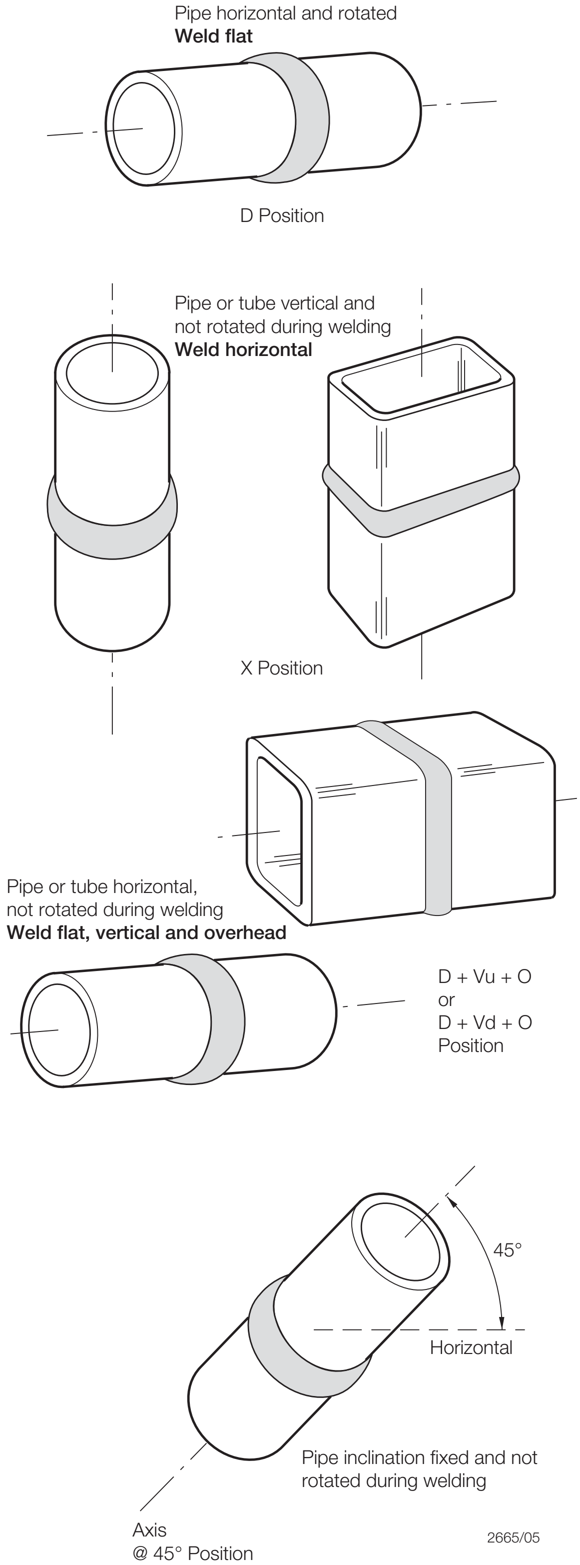
2.4 Welding of steel test assemblies

2.4.1 Welding of the test assembly is to be carried out in accordance with the agreed pWPS. Where, during the progress of the test, it is found necessary to change the conditions specified on the pWPS, this is to be brought to the attention of the Surveyor. If agreed, the test may be permitted to continue with the new conditions and these are to be recorded.



Position of test plates for plate assemblies

Fig. 12.2.2(a) Plate butt weld test positions



Position of pipes and welds for qualification weld test assemblies

Fig. 12.2.2(b) Pipe butt weld test positions

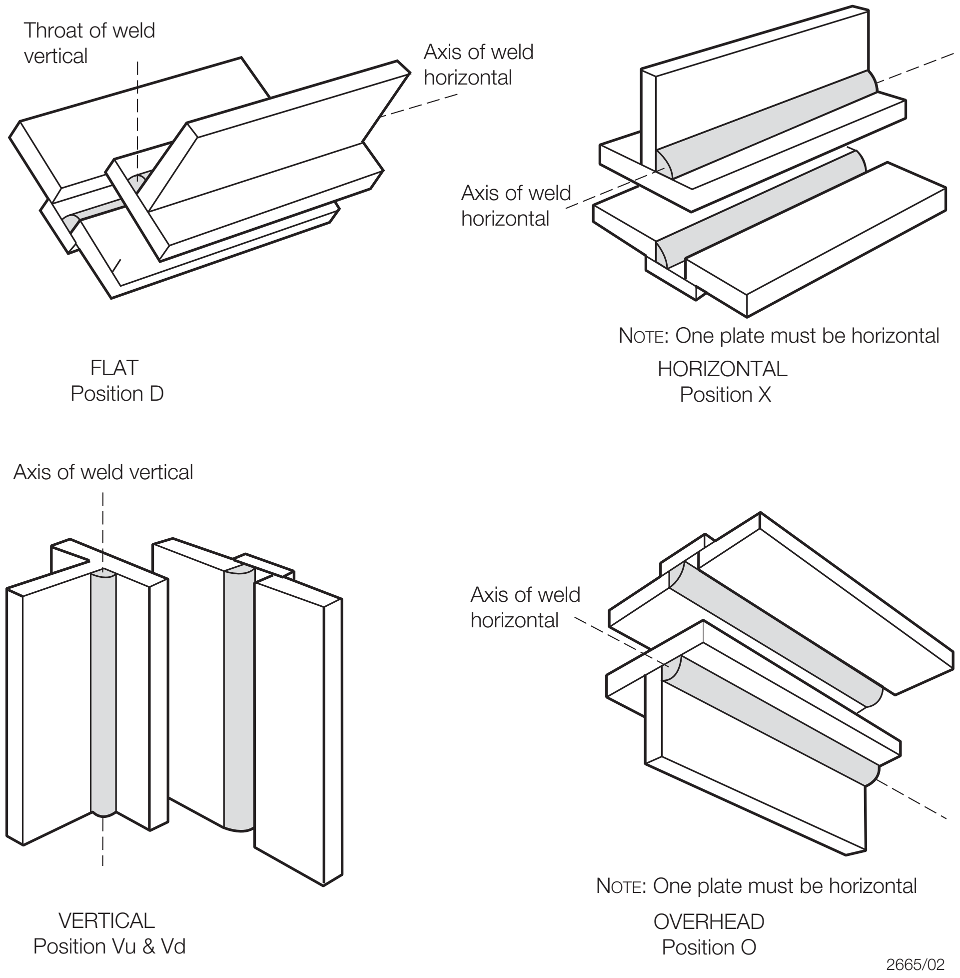


Fig. 12.2.2(c) Plate fillet weld test positions

2.4.2 Where the production work requires welding over tack welds, the test is to simulate this condition and the tack welds are to be included in the inspection length of the test weld and their position recorded.

2.4.3 For manual and semi-automatic welding processes, weld stops and re-starts are to be included in the inspection length of the test weld.

2.4.4 Fillet weld test assemblies are welded on one side only.

2.4.5 Where the construction welding is predominately fillet welding, in addition to the butt weld qualification test, a fillet weld qualification test is to be performed to confirm that acceptable weld quality is achieved.

2.5 Non-destructive examination (NDE)

2.5.1 On completion of welding, prior to sectioning for mechanical tests, the inspection length of the test assembly is to be subjected to both visual examination and surface crack detection.

2.5.2 Butt weld assemblies are also to be subjected to radiographic or ultrasonic examination over the whole inspection length of the weld.

2.5.3 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

2.5.4 Where post-weld heat treatment is required, NDE is to be performed after the heat treatment is complete.

2.5.5 All NDEs are to be carried out in accordance with the requirements of Ch 1,5. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply. Linear porosity is not permitted.

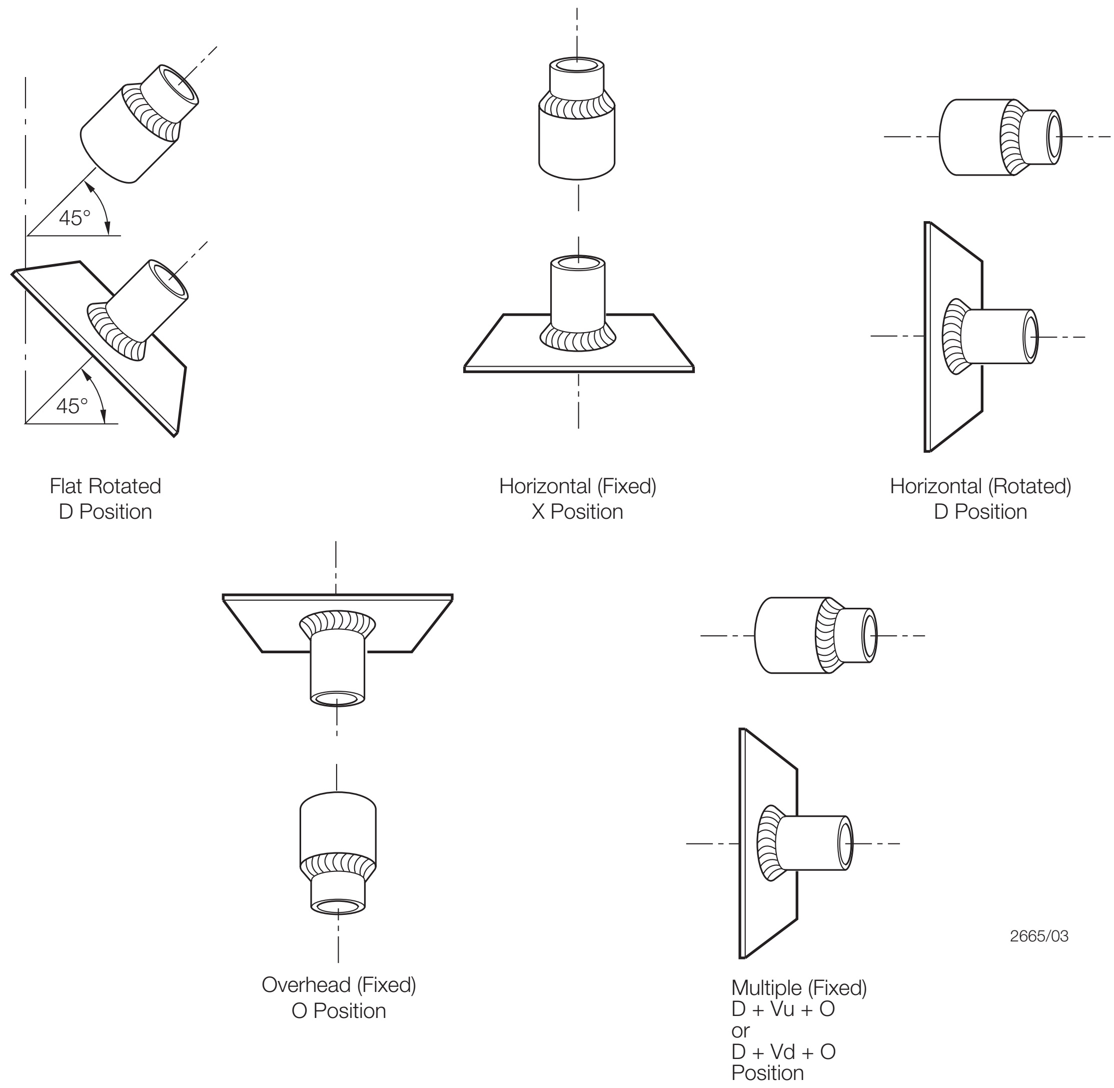


Fig. 12.2.2(d) Pipe fillet weld test positions

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality (in accordance with 2.5.5) are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.5.7 Where the test assembly does not satisfy the non-destructive examination acceptance criteria, the test is to be rejected. A duplicate test assembly may be welded using the original welding conditions. If this fails NDE, the welding procedure is to be considered as incapable of achieving the requirements without modification.

2.5.8 Subject to prior agreement with the Surveyor, where unacceptable imperfections are of a volumetric nature and are localised in one small area of the test assembly, the test may be permitted to continue and specimens for destructive testing may be removed, avoiding this area.

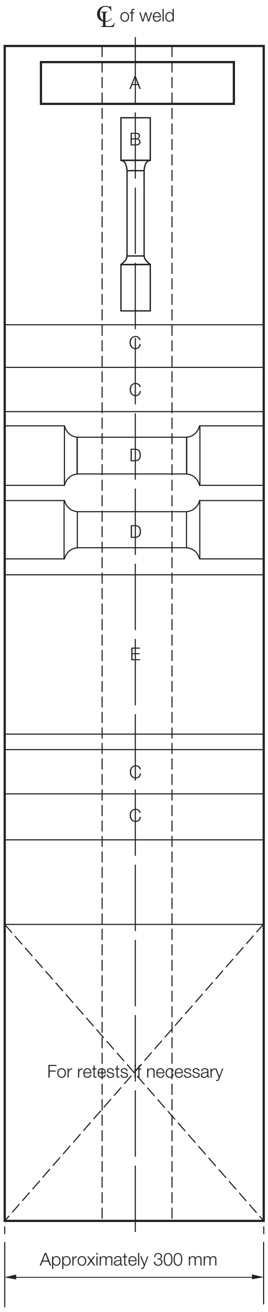
2.6 Destructive tests – General requirements

2.6.1 The weld test assembly may only be sectioned for destructive testing after any heat treatment and the required non-destructive examinations have been completed successfully.

2.6.2 The dimensions of the test specimens and testing conditions are to be in accordance with the requirements specified in Chapter 2.

2.6.3 The results of destructive tests are to be assessed in accordance with the acceptance criteria specified in 2.12, unless other, more stringent requirements are specified for the application.

2.6.4 Where a weld test is made between materials of different grades, the acceptance criteria that are to be applied are those applicable to the lower grade material.



Test requirements

A One macro including hardness survey

B All weld metal tensile test

C Four bend tests.
Two root bends and two face bends for thickness up to 12 mm.
For thickness above 12 mm four side bends

D Two transverse tensiles

E Five sets of Charpy V-notch impact tests, notched at the following positions:
1 set at weld centre
1 set at fusion line (FL)
1 set at FL + 2 mm
1 set at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
1 set at FL + 10 mm (if required)

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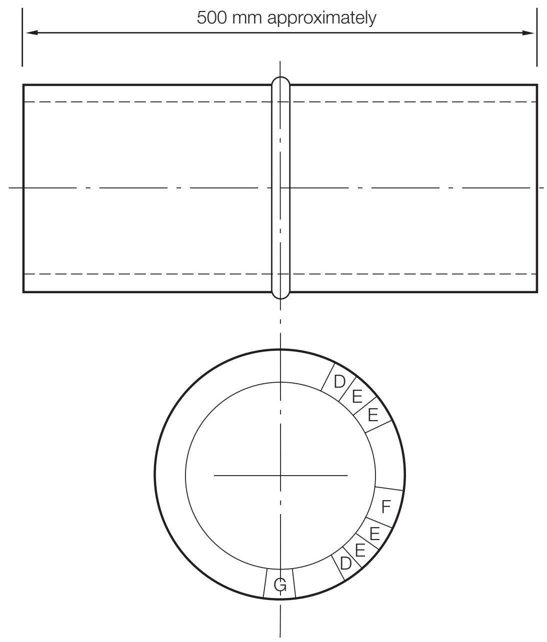
Fig. 12.2.3
Butt welds in plate and pipe over 750 mm diameter



The diameter of the test piece is to be a minimum of *D*/2
where
D is the maximum diameter of the pipe to be welded in construction

Test requirements

A Visual examination

B Surface crack detection

C 100% radiographic examination

D Two transverse tensile tests

E Four bend tests.
Four side bends for thickness greater than 12 mm.
In other cases, two face and two root bends

F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)

G One macro specimen including hardness survey

Fig. 12.2.4
Butt welds in pipe less than 750 mm diameter

2.7 Destructive tests for steel butt welds

2.7.1 The test assembly is to be sectioned for mechanical testing in accordance with Figs. 12.2.3 or 12.2.4.

2.7.2 The longitudinal all weld metal tensile test specimen is to be of circular cross-section as detailed in Ch 11,2.1.1. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from each respective area of the weld. This does not apply to the process or consumables used to make the root or first weld run. During the test, the yield or proof stress, ultimate tensile strength, and elongation to failure are to be recorded.

2.7.3 Where approved welding consumables have been used, the longitudinal all weld metal tensile test may be omitted. For Type C independent tanks intended for liquefied gases, the all weld tensile test is mandatory for all welding procedure tests.

2.7.4 The transverse tensile test specimen is to be of full thickness with the dimensions shown in Ch 11,2.1.1. The tensile strength and fracture locations are to be reported.

2.7.5 Where the maximum load required to fracture the transverse tensile specimen is likely to exceed the capacity of the tensile testing equipment, several tensile specimens may be removed through the thickness and tested. Specimens are to be prepared such that they overlap in the thickness direction so that the full plate thickness is tested.

2.7.6 Transverse bend specimens of rectangular section are to be prepared with the weld centred in the middle of the specimen as shown in Fig. 12.2.5. For material of thickness 12 mm or greater, the face and root bends may be substituted by side bend tests. Where there is a significant difference between the strength of the weld and base material, longitudinal bend specimens may be used.The weld reinforcement may be removed by grinding or machining prior to testing and the edges rounded to a radius not exceeding 10 per cent of the specimen thickness. Each specimen is to be bent through an angle of at least 180°. The bend test ratio is to be the lesser of the following:

(a) D_f = $(D/t) + 1$

or

(b) D_f = $100/E_m$ (rounded up to the next whole number)

where

D_f = is the bend test ratio

(D/t) = is the value from Tables 11.3.3, 11.4.3 or 11.8.2 in Chapter 11, as appropriate

E_m = is the minimum specified percentage elongation for the test material (based on a proportional gauge length of $5,65\sqrt{S_o}$)

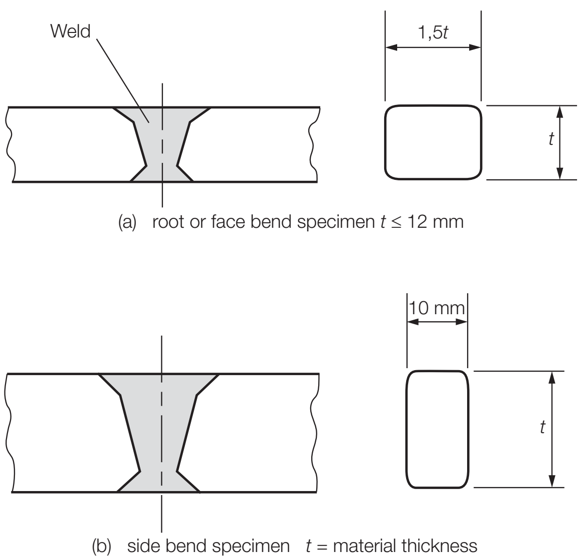


Fig. 12.2.5 Transverse bend test specimens

2.7.7 Where the weld test is made between different material types, the requirements of 2.7.8 are to be applied to the material with the lower toughness specification.

2.7.8 For hull structural steels, impact test specimens are to be prepared from the locations shown in Figs. 12.2.6 or 12.2.7, with the notch perpendicular to the plate surface and have the dimensions and proportions in accordance with Ch 2,3. Where more than one welding process or type of consumable has been used to make the weld, test specimens are also to be removed from these respective parts of the weld. Note that this does not apply to the welding process or consumables used solely to make the root or first weld run. Where the weld thickness exceeds 50 mm, an additional set of impact tests is required from the root area of the weld irrespective or whether different welding process or welding consumables are used as shown in Figs. 12.2.6 and 12.2.7.

2.7.9 For offshore structures and pressure vessels, impact test specimens are not required to be notched at the FL + 10 mm location. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from the respective areas of the weld. This does not apply to the process or consumables used solely to make the root or first weld run.

2.7.10 For pressure vessels and tanks employed in transportation of liquefied gases, Charpy impact test locations from the weld and heat affected zone are to be in accordance with Fig. 12.2.8.

2.7.11 At least one macro examination specimen is to be removed from the test plate, near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone and be prepared and etched to clearly reveal the weld runs and the heat affected zone. Examination is to be performed under a magnification of between x5 and x10.

2.7.12 A chemical analysis of the weld metal is to be performed on the macro specimen where approved welding consumables have not been used. The results are to comply with the limits given in the welding consumable specification.

2.7.13 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.9, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507/1.

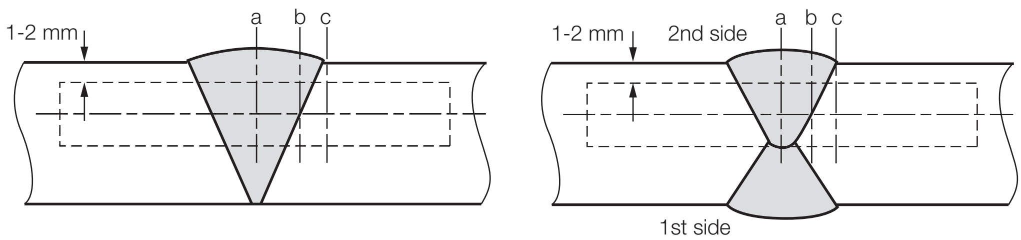
2.8 Destructive tests for steel fillet welds

2.8.1 Fillet weld test assemblies are to be sectioned for destructive testing in accordance with Fig. 12.2.1(c) and as follows:

(a) two fracture tests;
(b) three macro-sections;
(c) one hardness survey.

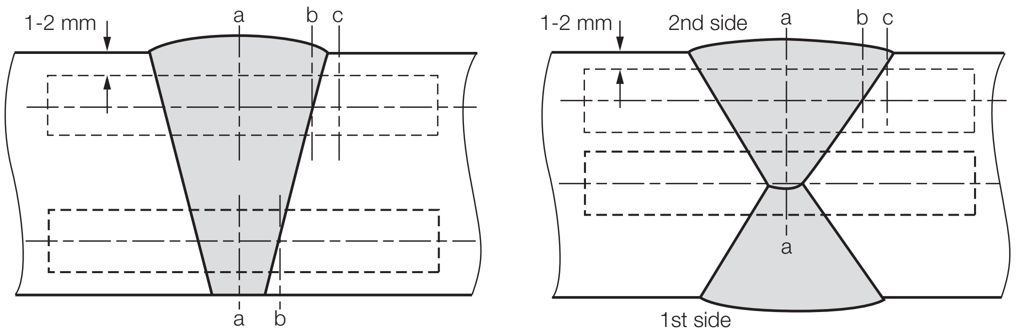
2.8.2 Two fracture test specimens are to be removed from the test weld and are to be subjected to testing by bending the upright plate onto the through plate to produce fracture, as shown in Fig. 12.2.1(c).

(a) $t \leq$ 50 mm, *see* Note



NOTE
For one side single run welding over 20 mm notch location ‘a’ is to be added on root side

(a) $t >$ 50 mm



Notch locations:
a : centre of weld ‘WM’
b : on fusion line ‘FL’
c : in HAZ, 2mm from fusion line

Fig. 12.2.6 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

2.8.3 At least three macro examination specimens are to be removed from the test plate. The specimens are to include the complete cross-section of the weld and the heat affected zone and is to be prepared to clearly reveal the weld runs and the heat affected zone. One of the specimens is to include a weld stop/start position. Examination is to be performed under a magnification of between x5 and x10.

2.8.4 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.10, using a test load not exceeding 10 kg.

2.9 Destructive tests for T, K, Y steel nozzle welds

2.9.1 Full penetration ‘T’, ‘K’ and ‘Y’ joints for structural applications and nozzle welds for pressure vessels are to be sectioned for testing in accordance with Fig. 12.2.11 and tested as detailed below:
(a) three macro specimens;
(b) impact tests from the weld, fusion line and fusion line + 2 (where the material thickness permits);
(c) one hardness survey.

In addition, butt weld tests are to be performed in accordance with 2.7, using the same welding conditions, in order to verify acceptable weld and heat affected zone properties.

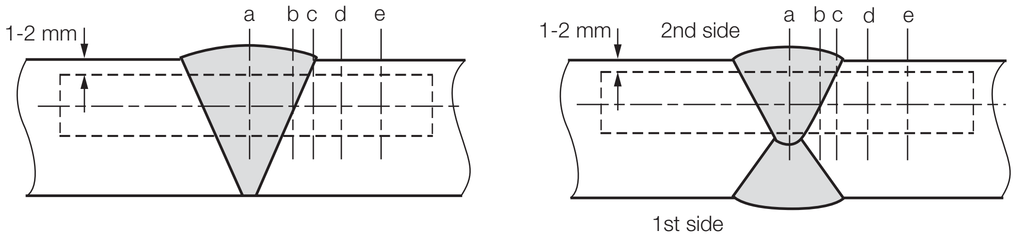
2.9.2 The impact tests are to be removed from the vertical (up) position ‘B’ in Fig. 12.2.11 and tested in accordance with 2.7.8.

2.9.3 A Vickers hardness survey is to be performed on the macro-section removed from position ‘A’ or ‘C’ in accordance with that shown in Fig. 12.2.12 using a test load not exceeding 10 kg.

2.10 Destructive tests for steel pipe branch welds

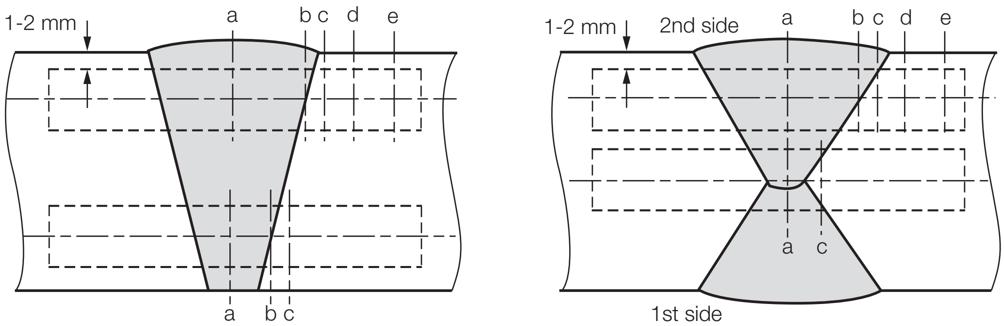
2.10.1 Pipe branch welds may be by either full penetration, partial penetration or fillet welded, depending on the application and the approved plans. Where these types of welded joints are used, tests are to be performed which simulate the construction conditions.

(a) *t* ≤ 50 mm, *see* Note



NOTE
For one side welding with thickness over 20 mm notch location 'a', 'b' and 'c' are to be added on root side

(a) *t* > 50 mm



Notch locations:
a : centre of weld 'WM'
b : on fusion line 'FL'
c : in HAZ, 2 mm from fusion line
d : in HAZ, 5 mm from fusion line
e : in HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm

Fig. 12.2.7 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

2.10.2 The test weld assembly is to simulate the smallest angle between the branch and main pipe and is to be subjected to macro-examination and hardness testing, as follows:

(a) For a branch weld that is full penetration, testing is to be performed in accordance with the requirements for 'T', 'K' and 'Y' joints in 2.9.
(b) For a branch weld that is either a partial penetration or fillet weld, testing is to be in accordance with the requirements for fillet welds in 2.8.

2.11 Destructive tests for weld cladding of steel

2.11.1 Where weld cladding or overlay is allowed by Chapter 13, and is considered as providing strength to the component to which it is welded, the type and location of test specimens are to be in accordance with Fig. 12.2.13, except that micro-sections are not required. Impact tests may be omitted where the base material does not have specified impact properties. The longitudinal tensile and bend tests are to be tested in a similar manner to transverse specimens specified in 2.7.2 and 2.7.6, respectively.

2.11.2 Where the weld cladding is not considered as contributing to the strength of the component, but is required for corrosion or wear resistance, the type and location of test specimens are to be in accordance with Fig. 12.2.13, except that tensile and impact tests are not required.

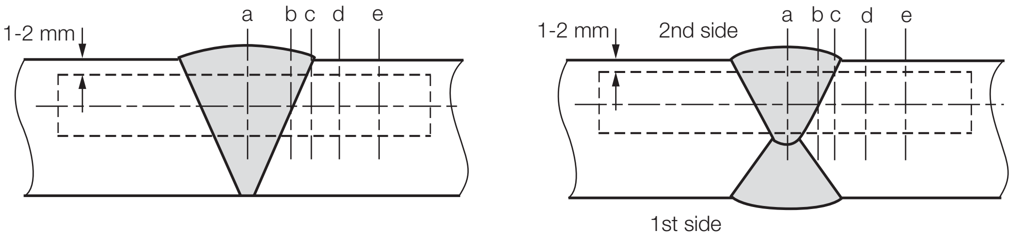
2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, on the final weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.

2.12 Mechanical test acceptance criteria for steels

2.12.1 **Longitudinal all weld metal tensile test**:

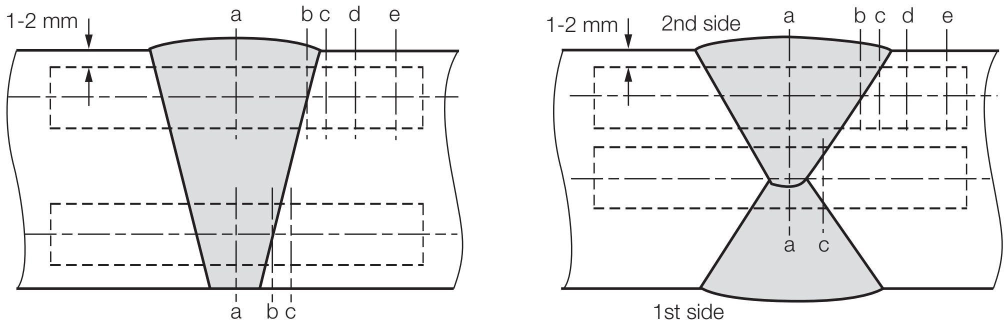
(a) In general, the longitudinal all weld tensile test is to meet the minimum properties specified in Tables 11.3.2 or 11.4.2 in Chapter 11, as appropriate to the grade of steel and welding process used in the test.
(b) Where the application is such that no consumable approvals are specified in Chapter 11, the longitudinal all weld tensile test tensile is to meet the minimum properties specified for the base materials used in the test.

(a) *t* ≤ 50 mm, *see* Note



NOTE
For one side welding with thickness over 20 mm notch locations ‘a’, ‘b’ and ‘c’ are to be added on root side

(a) *t* > 50 mm



Notch locations:
a : centre of weld ‘WM’
b : on fusion line ‘FL’
c : in HAZ 1 mm from fusion line
d : in HAZ 3 mm from fusion line
e : in HAZ 5 mm from fusion line
f : in base metal remote from weld (Type C independent tanks only)

Fig. 12.2.8 Locations of V-notch tests for butt welds intended for liquefied gas containment systems

(c) For pressure vessels manufactured from carbon or carbon/manganese steels, the tensile strength from the longitudinal all weld tensile test is not to be less than the minimum specified for the plate material and is not to be more than 145 N/mm^2 above this value, *see* Ch 13,4.8.3.

(d) For tanks intended for liquefied gases, the weld metal strength may be lower than the minimum specified for the base metal provided that the application has design approval. In such cases the strength is not to be less than that specified in the approved design.

2.12.2 **Transverse tensile test**: The tensile strength measured from the transverse tensile test is not to be less than the minimum specified for the base material used in the test. For tanks intended for liquefied gases, a lower ultimate tensile may be accepted subject to design approval as in 2.12.1(d).

2.12.3 **Bend tests**:

(a) In general, bend tests are to exhibit no defects exceeding 3,0 mm measured in any direction across the tension face of the specimen after being bent over the required diameter of former to the appropriate angle.

(b) Bend tests for pressure vessel applications are to exhibit no defects exceeding 3,0 mm measured along the specimen or 1,5 mm measured transverse to the specimen axis, after bending.

(c) In all cases, premature failure of the bend tests at the edges of the specimen is to not be cause for rejection unless these are associated with a weld defect.

2.12.4 **Impact toughness tests**:

(a) Impact test specimens for hull construction are to be tested at the temperature, and are to achieve the minimum impact energy, as specified in Tables 12.2.2 and 12.2.3.

(b) Impact test specimens for applications other than hull construction are to be tested at the same temperature and achieve the same minimum energy values, as specified for the base materials used in the test.

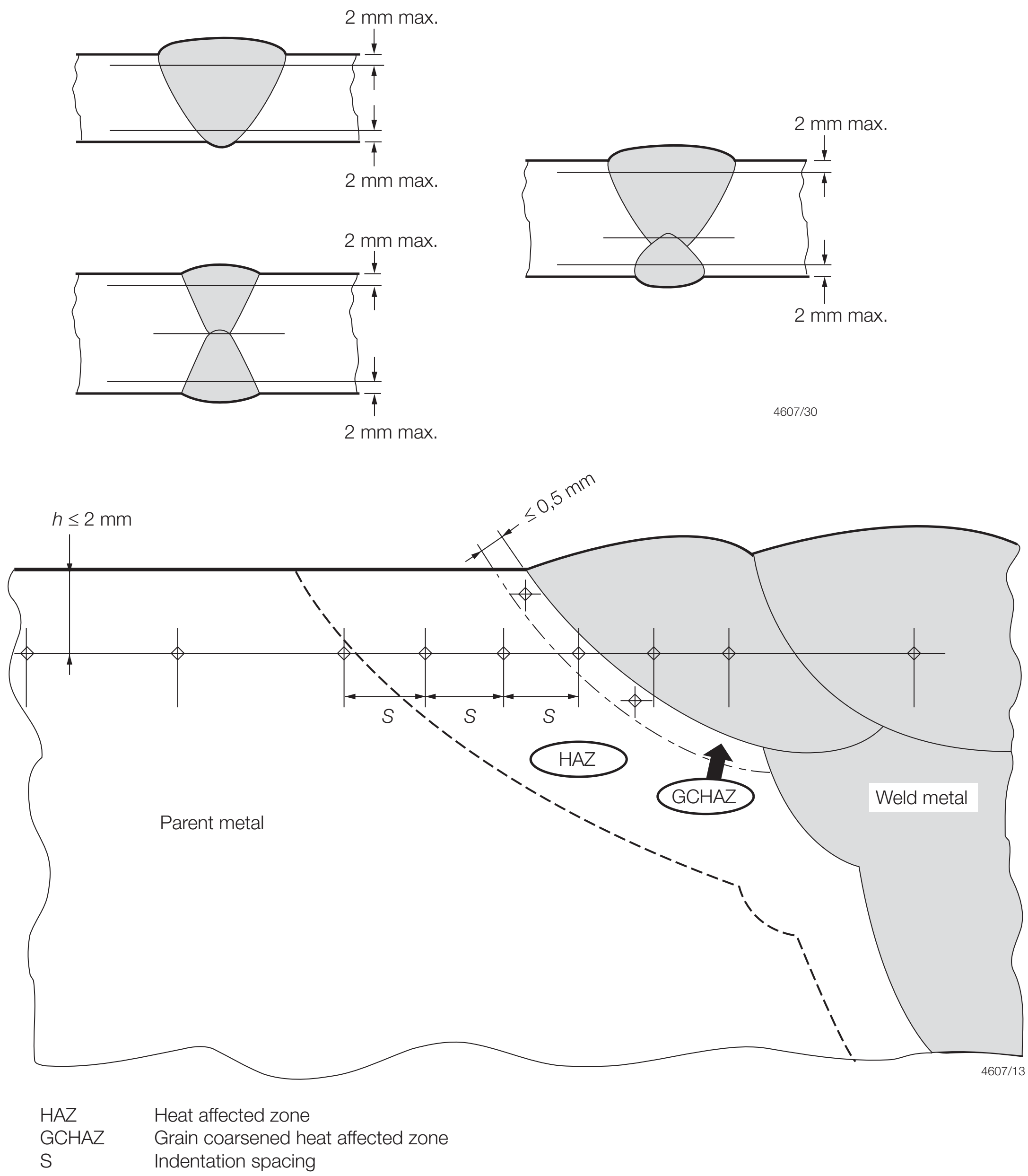


Fig. 12.2.9 Hardness testing locations for butt welds

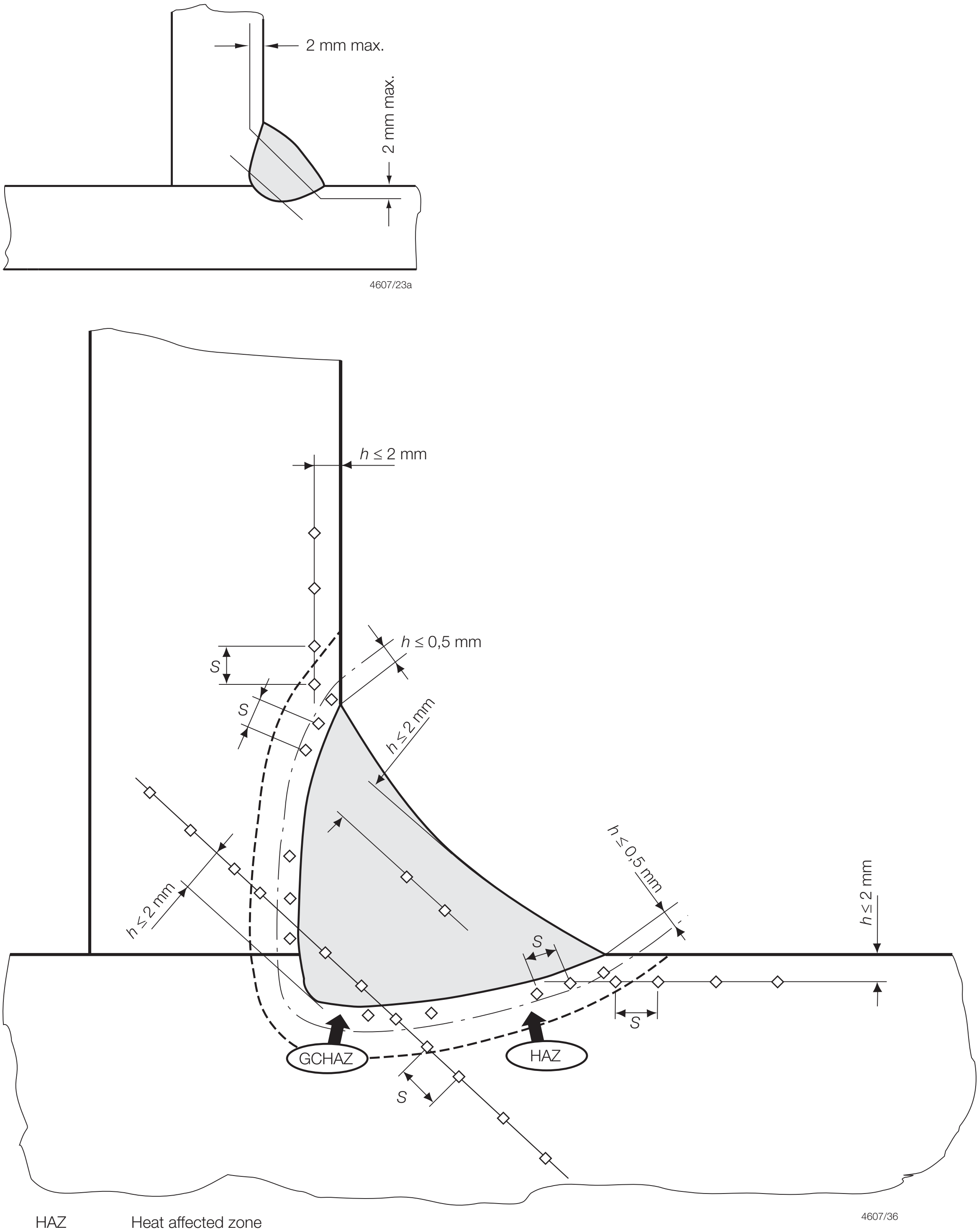
(c) Impact test acceptance criteria are to be in accordance with the above unless the Rules applicable to the particular construction specify more stringent requirements.

(d) For quench and tempered steels, the required test temperature and absorbed energy are to be in accordance with that specified for the parent materials.

2.12.5 **Macro-examination**: The macro-section is to reveal an even weld profile blending smoothly with the base material. The weld dimensions are to be in accordance with the requirements of the pWPS and any defects present are to be assessed against the non-destructive examination acceptance criteria given in 2.5.5.

2.12.6 **Hardness surveys**: The maximum hardness value reported, is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2.

2.12.7 **Weld fracture or break tests (for pressure vessel test welds)**: The faces of the broken fillet weld fracture or weld break test are to be examined for defects and assessed in accordance with the non-destructive acceptance criteria given in ISO 5817 Level B, except for excess convexity and excess throat thickness where Level C will apply.



HAZ	Heat affected zone
GCHAZ	Grain coarsened heat affected zone
S	Indentation spacing

Fig. 12.2.10 Hardness test locations for fillet welds

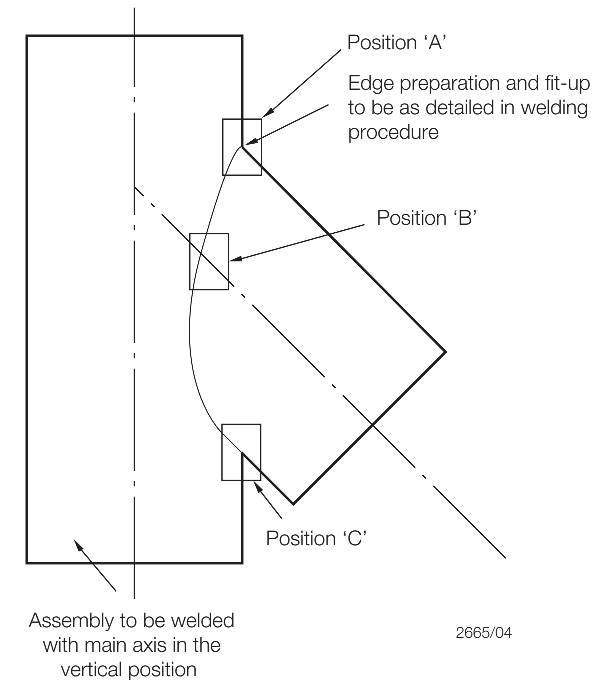


Fig. 12.2.11
Location of macro-examination test specimens for T, K and Y joints

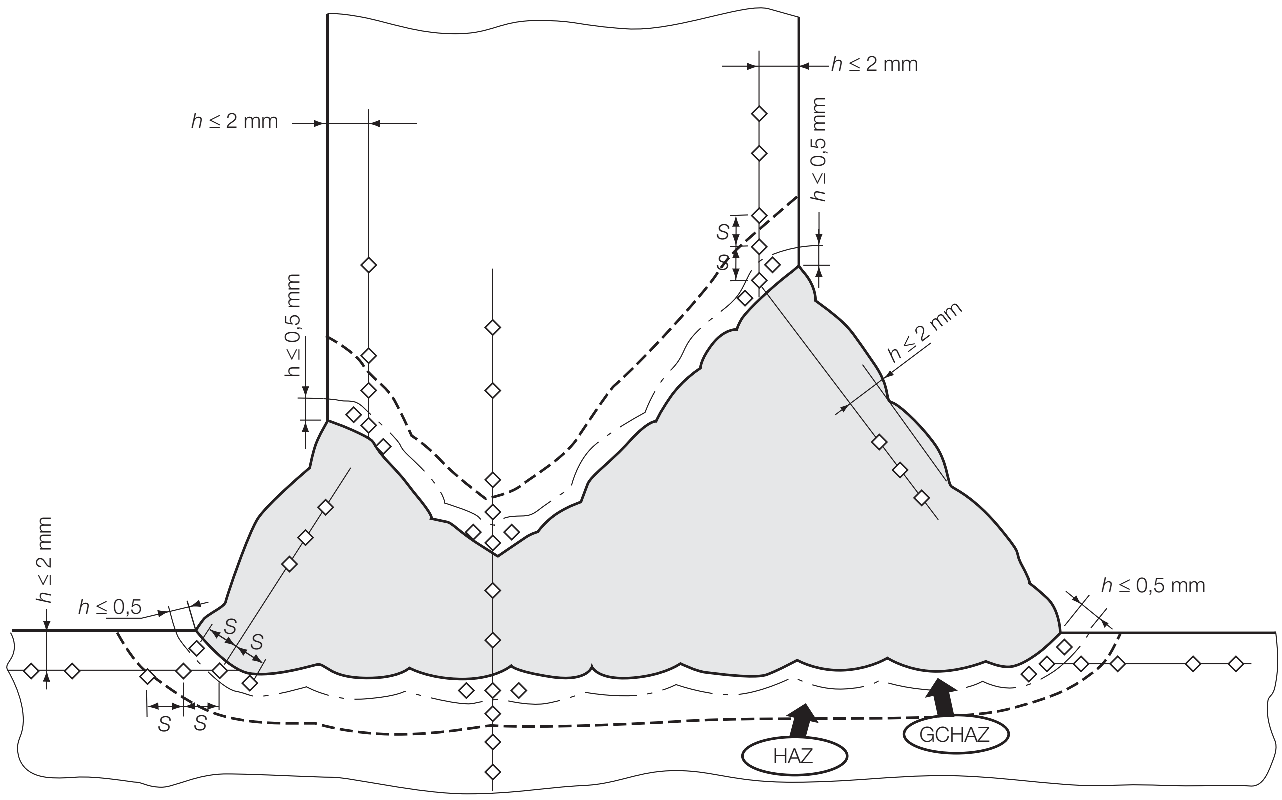
2.13 Failure to meet requirements (Retests)

2.13.1 Where a tensile, bend or hardness specimen fails to meet requirements, further test specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.1.

2.13.2 Where an impact specimen fails to meet requirements, a further set of three specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.4.

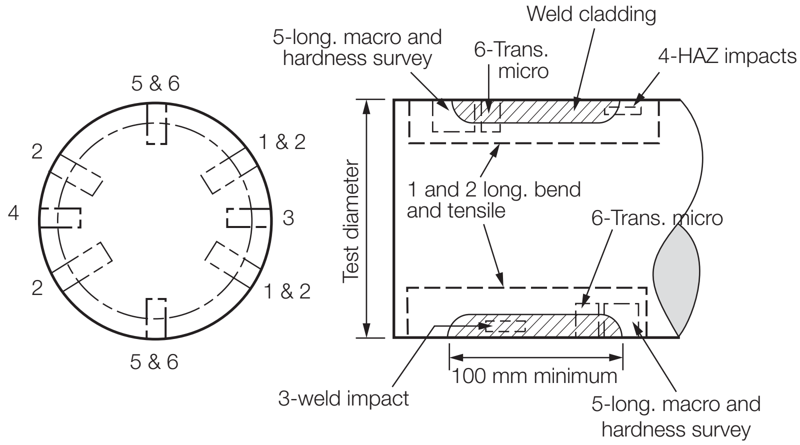
2.13.3 Where a macro specimen reveals a defect that is planar in nature, the welding procedure test is to be considered as not satisfying the requirements and a new test assembly is required.

2.13.4 Where a macro specimen does not meet requirements as a result of a volumetric imperfection exceeding the permitted size, two additional specimens may be removed from the same test weld and examined. If either of these macro-sections also fails to satisfy the requirements, the welding procedure is to be considered as not having met the requirements.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.12 Hardness test locations for T, K and Y joints



Test specimens
1 Longitudinal tensile test to include the weld metal, heat affected zone (HAZ) and base metal.
2 Longitudinal side bend test to include the weld metal, heat affected zone (HAZ) and base metal.
3 Weld metal Charpy V notch impact test.
4 HAZ Charpy impact test from Fusion Line and Fusion Line + 2 mm.
5 Longitudinal macro-section and hardness survey.
6 Transverse micro-section.

NOTE
In the case of shafts and pipes of circular section, the longitudinal direction is parallel to the centreline of the shaft or pipe axis.

Fig. 12.2.13 Type and location of test specimens for weld cladding

Table 12.2.2 Impact test requirements for butt joints ($t \leq 50$ mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C) *see* Note 4	Value of minimum energy absorbed (J), *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3 B, *see* Note 3, D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39

NOTES
1. Steel with yield strength greater than 390 N/mm^2 is not permitted in thickness less than 50 mm, *see* Table 3.3.1 in Chapter 3.
2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.
4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

2.13.5 If there is a single hardness value above the maximum values specified, additional hardness tests are to be carried out, either on the reverse of the specimen, or after sufficient grinding of the tested surface. None of the additional hardness values is to exceed the maximum hardness values specified, otherwise the welding procedure is to be considered as not having met the requirements.

2.13.6 Where there is insufficient material available in the welded test assembly to provide re-test specimens, subject to prior agreement with the Surveyor, a second assembly may be welded using the same conditions as the original test weld.

Table 12.2.3 Impact test requirements for butt joints (*t* > 50 mm) *see* Note 1

Grade of steel	Test temperature (ºC) *See* Note 2	Value of absorbed energy (J, min), *see* Note 2		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A	20	34	34	34
B	0	34	34	34
D	0	47	38	38
E	–20	47	38	38
AH32, AH36	20	47	41	41
DH32, DH36	0	47	41	41
EH32, EH36	–20	47	41	41
FH32, FH36	–40	47	41	41
AH40	20	50	46	46
DH40	0	50	46	46
EH40	–20	50	46	46
FH40	–40	50	46	46
EH47	–20	64	64	64

NOTES
1. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
2. For the Naval ships both the test temperature and value of minimum absorbed energy are to be those specified for the parent material.

2.14 Test records

2.14.1 The procedure qualification record (PQR) is to be prepared by the manufacturer and is to include details of the welding conditions used in the test specified in 2.2 and the results of all the non-destructive examinations and destructive tests, including re-tests.

2.14.2 Provided that the PQR lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the PQR may be endorsed by the Surveyor as satisfying the requirement of the Rules, *see also* 1.1.4.

2.15 Range of approval

2.15.1 A welding procedure qualification test that has successfully met the requirements may be used for a wider range of applications than those used during the test.

2.15.2 Changes outside of the ranges specified are to require a new welding procedure test.

2.15.3 Other ranges of approval from those specified in this Section may be agreed with the Surveyor, provided that they are in accordance with recognised National or International Standards.

2.15.4 **Manufacturer**. A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

2.15.5 **Welding process and technique**. The welding process and welding techniques approved are to be those employed during the welding procedure qualification test. Where multiple welding processes are used, these are to be employed in the same order as that used in the welding procedure qualification test. However, it may be acceptable to delete or add a welding process where it has been used solely to make the first weld run in the root of the joint, provided back gouging or grinding of the root weld is specified on the WPS. For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.

2.15.6 **Welding positions**. Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position, and the lowest heat input position, and all applicable tests are to be made on those assemblies. The above excludes welding in the vertical position with travel in the downward direction which will always require separate qualification testing and only be acceptable for that position.

2.15.7 **Joint types**. A qualification test performed on a butt weld may be considered acceptable for fillet and partial penetration welds, provided the same welding conditions are used. The range of approval depending on the type of joint for butt welds is given in Table 12.2.4.

Table 12.2.4 Range of approval for different types of butt joints

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing Without backing	A B	A,C A,B,C,D
	Both sides	With gouging Without gouging	C D	C C,D

2.15.8 **Range of material types**:

(a) A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three toughness grades lower specified minimum toughness level.

(b) A qualification test performed on H47 strength grade steels may be used to weld the steel of the same strength level or grade H40 and all lower toughness grades to that tested.

(c) For high strength quenched and tempered steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested. The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

(d) For weldable C and C-Mn steel forgings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel forgings does not qualify other delivery conditions and vice versa.

(e) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa.

Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

2.15.9 **Thickness and diameter range**:

(a) For straight butt welds, the material thickness range to be approved is to be based on the thickness of the test piece and the type of weld as shown in Table 12.2.5.

(b) For butt welds between plates of unequal thickness, the lesser thickness is the ruling dimension.

(c) For fillet welds and 'T' butt welds, Table 12.2.5 is to be applicable to both the abutting and through member thicknesses. In addition to the requirements of Table 12.2.5, the range of approval of throat thickness '*a*' for fillet welds is to be as follows:

- single run: 0,75*a* to 1,5*a*
- multi-run: as for butt welds with multi-run (i.e. $a = t$)

Table 12.2.5 Welding procedure thickness approval range – Butt welds

Test thickness, *see* Note 1 (t in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes 3 and 4	All single-run or two-run two-run (T technique) butt welds
$t \leq 3$	t to $2t$	$0,7t$ to $1,1t$
$3 < t \leq 12$	3 to $2t$	$0,7t$ to $1,1t$
$12 < t \leq 100$	$0,5t$ to $2t$, *see* Note 2	$0,7t$ to $1,1t$ *see* Note 5
$t > 100$	$0,5t$ to $1,5t$	$0,7t$ to $1,1t$ *see* Note 5

NOTES
1. Where the test plates have dissimilar thickness, the thickness, t, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.
2. Subject to a maximum limit of 150 mm.
3. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.
4. For vertical down welding, the test piece thickness, t, is the upper limit of the range of application.
5. For processes with heat input over 5,0 kJ/mm, the upper limit of the range of approval is to be 1,0 t.

(d) Notwithstanding any of the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted.

(e) The material diameter range to be approved is to be based on the diameter of the test piece and type of weld as shown in Table 12.2.6.

Table 12.2.6 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
$D \leq 25$ mm	$0,5D$ to $2D$
$D > 25$ mm	$> 0,5D$, *see* Note 2

NOTES
1. D is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.
2. Lower diameter range limited to 25 mm minimum.

2.15.10 **Welding consumables**:

(a) For manual and semi-automatic welding used for the fill and capping weld runs, it may be acceptable to change the brand or trade name of the welding electrode or wire from that used in the test, provided the proposed alternative has the same or higher approval grading and the same flux type (e.g. basic low hydrogen, rutile, etc.) as used in that test.

(b) For the consumable used to make the root weld of full penetration butt welds made from one side only, no change in the type or trade name of the consumable or backing material is permitted. Alternative backing materials may be used provided they are equivalent to those used for approval. Where the approved backing material is a low hydrogen grade and the steel being welded requires a low hydrogen backing material, testing of the alternative backing material is to confirm compliance with the requirements of Ch 11,7

(c) For processes with heat input over 5 kJ/mm, no change in the type or trade name of the consumable is permitted.

2.15.11 **Shielding gas**. For gas shielded welding processes, a change in shielding gas composition from that used in the test will require a new qualification test.

2.15.12 **Heat Input**. The upper limit of heat input approved is 25 per cent greater than that used in the test, or 5,5 kJ/mm, whichever is the smaller. With heat input over 5,0 KJ/mm, the upper limit is 10 per cent above that used in the test. In all cases, the lower limit of heat input approved is 25 per cent lower than that used in the test.

2.15.13 **Current type**. The current type used during the qualification test is to be the only type approved. Additionally, changes from or to pulsed current require new qualification tests.

2.15.14 **Preheat temperature**. The temperature used during the test is to be the minimum approved. Higher temperatures may be specified for production welds up to the maximum interpass temperature. Where hardness tests have been performed that exhibit results near the maximum permitted, an increase in preheat temperature is required when welding material of greater thickness than that used in the test.

2.15.15 **Interpass temperature**. The maximum interpass temperature recorded during qualification testing is to be the maximum approved. Lower temperatures may be specified for production welding, but no lower than the minimum preheat temperature.

2.15.16 **Post-weld heat treatment**. A qualification test performed with no post weld heat treatment is only acceptable for production welding where no heat treatment is applied. Where the qualification test has included a post weld heat treatment, this is to be applied to all welds made with the welding procedure. The average specified soak temperature may vary by up to 25°C from that tested.

2.15.17 **Shop primers.** Welding procedure qualification with shop primers qualifies welds without primer, but not vice versa.

2.16 Welding procedure specification (WPS)

2.16.1 A welding procedure specification (WPS) is to be prepared by the manufacturer detailing the welding conditions and techniques to be employed for production welding. The WPS is to be based on the conditions and variables used during the qualification test, and is to include all the ranges of the essential variables specified in 2.2.1 and 2.15.

2.16.2 The WPS should reference the procedure qualification record upon which it is based and is to be approved by the Surveyor prior to commencing production welding.

■ *Section 3* Specific requirements for stainless steels

3.1 Scope

3.1.1 The requirements of this Section relate to the group of steel materials classed as stainless steels and include austenitic and duplex grades and martensitic grades.

3.1.2 In all cases, welding procedure tests are to be performed generally in accordance with Section 2 with the specific requirements specified below.

3.2 Austenitic stainless steels

3.2.1 The requirements of this Section relate to the group of stainless steel materials that are austenitic at ambient and sub-zero temperatures, (e.g., 304L, 316L types), *see* Table 3.7.1 in Chapter 3.

3.2.2 Impact tests are to be performed from specimens removed from the weld metal. Tests in the heat affected zone are not required.

3.2.3 Hardness tests are generally not required.

3.2.4 For cryogenic or corrosion resistant applications, the ferrite content in the weld cap region is to be measured and is to be in the range 2 to 10 per cent, with the exception of grades S 31245 and N 08904 where the content is to be nominally zero.

3.2.5 A qualification test performed on an austenitic grade may be considered acceptable for welding other austenitic steels with the same or lower level of alloying elements and the same or lower tensile strength.

3.2.6 A qualification test performed for cryogenic applications may be considered acceptable for chemical applications, but not vice versa.

3.3 Duplex stainless steels

3.3.1 The requirements of this Section relate to the group of stainless steel materials that have a ferritic-austenitic structure and are usually referred to as duplex or super duplex stainless steels (e.g.,S 31803, S 32760).

3.3.2 Impact test specimens are to be removed from the weld and heat affected zone in accordance with Section 2 with the exception that impact test specimens notched at the FL + 10 mm location are not required. The specimens are to be tested at a temperature of –20°C or the minimum design temperature whichever is the lower and exhibit a minimum average energy of 40 J.

3.3.3 The corrosion resistance is to be maintained in the welded condition and the following tests are to be performed to demonstrate acceptable resistance, unless agreed otherwise.

(a) A sample is to be removed from the weld and heat affected zone for micro-structural examination and is to be suitably prepared and etched so that the micro-structures of the weld and heat affected zones can be examined at a magnification of x200 or higher. The micro-structure of the weld and heat affected zone is to be examined, the percentage grain boundary carbides and intermetallic precipitates is to be reported.

(b) The ferrite content in the un-reheated weld cap and cap HAZ along with the weld root and root HAZ are to be measured and reported. The ferrite content is to be in accordance with Table 12.3.1. Where the intended construction is such that the corrosion medium is only in contact with one surface of the weld (i.e., the weld root), the ferrite determination need only be reported in that surface area.

(c) Corrosion testing is to be performed on samples removed from the weld such that both the weld and HAZ are included in the test. The critical pitting temperature is to be determined in accordance with ASTM G48 Method C and meet the requirements specified in Table 12.3.1. The cap and root surfaces are to be inspected for evidence of pitting and may require probing the surface with a needle. Pitting found on the ends of the specimen in the weld cross-section may be ignored. The use of the weight loss method for corrosion testing may be accepted subject to special consideration.

Table 12.3.1 Requirements for ferrite content and corrosion tests for duplex stainless steel test welds

Duplex Stainless Steel Material Grade	Weld and HAZ Ferrite content	Minimum Critical Pitting Temperature (CPT)
S 31260	30 to 70%	20°C
S 31803	30 to 70%	20°C
S 32550	35 to 65%	25°C
S 32750	35 to 65%	25°C
S 32760	35 to 65%	25°C

3.3.4 Where the test weld is between a grade of carbon steel and duplex stainless steel, the test requirements of 3.3.3(a) and (c) are not required and the ferrite content of the weld and the duplex heat affected zone are to be reported for information.

3.3.5 A qualification test performed on a duplex stainless steel grade may be considered acceptable for welding other duplex grades which have the same or less stringent mechanical or corrosion properties.

3.3.6 The range of heat input is not to vary by more than +10 per cent or –25 per cent from that used during testing.

3.4 Martensitic stainless steels

3.4.1 The requirements of this Section relate to the group of stainless steel materials that have a martensitic structure at ambient temperatures, *see* Table 4.5.1 in Chapter 4.

3.4.2 The results of the hardness survey results are to be reported for information purposes only.

3.4.3 A qualification test is considered acceptable only for the grade of material used in the test.

■ *Section 4* Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

4.1.1 The requirements for welding procedure qualification tests for aluminium alloys are to be in accordance with the general requirements of Section 2 with the following exceptions and specific requirements.

4.1.2 Non-destructive examination is to be performed in accordance with 2.5 and the assessment of results is to be in accordance with Table 12.4.1 and Table 12.4.2.

4.1.3 Acceptance of the mechanical tests is to be in accordance with Ch 11,9. Welding of the strain hardened and heat treatable aluminium alloys will generally result in a loss of tensile strength in the heat affected zone below that specified for the base materials and the tensile strength acceptance criteria to be applied is that specified for the material in the annealed or ‘as fabricated’ condition. Minimum values of tensile strength measured on the transverse tensile samples are given in Table 12.4.3.

4.1.4 Impact tests and hardness surveys are not required for aluminium alloys.

Table 12.4.1 Acceptance criteria for surface imperfections of aluminium alloys

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0,1s$ or $0,1a$ max. 1,0 mm
Uniformly distributed porosity (*see* Note 1)	2012	≤ 0,5% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	Not permitted
Intermittent undercut	5012	$h \leq 0,1t$ or 0,5 mm (whichever is the lesser)
Excess weld metal (*see* Note 2)	502	$h \leq 1,5$ mm + $0,1b$ or 6 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 2)	515	$h \leq 0,05t$ or 0,5 mm (whichever is the lesser)
Linear misalignment (*see* Notes 3 and 4)	507	$h \leq 0,2t$ or 2,0 mm (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. To be in accordance with EN ISO 10042.
2. A smooth transition is required.
3. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is to be taken when the centrelines coincide.
4. Dimensional tolerances not specified in these Rules are to be mutually agreed between the manufacturer and the Surveyor.

4.1.5 Four side bend tests may be used in place of root and face bends where the test thickness exceeds 12 mm, and longitudinal bend tests may be used instead of transverse tests where the test weld is between different grades of alloy. Bend specimens are to be bent round a former in accordance with Table 11.9.1 in Chapter 11, with the exception that the 6000 series alloys may be bent round a former with $D/t = 7$.

4.1.6 The ranges of approval to be applied to the WPS are to be as specified for steel in 2.15 with the following exceptions:
(a) The welding positions approved are as detailed in Table 12.4.4.
(b) The aluminium alloys are grouped into three groups as follows:
- Group A: aluminium-magnesium alloys, with Mg content ≤3,5 per cent (alloy 5754).
- Group B: aluminium-magnesium alloys with 4 per cent ≤ Mg ≤5,6 per cent (alloys 5059, 5083, 5086, 5383 and 5456).
- Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082). For each group, the qualification made on one alloy qualifies the procedure also for the other alloys in the group, with equal or lower tensile strength after welding. The qualification made on group B alloys qualifies the procedure for Group A alloys also. Approval for the range of material grades is summarised in Table 12.4.5.

(c) The qualification of a procedure carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.4.6. In the case of butt joints between dissimilar thicknesses, t is the thickness of the thinner material. In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material. In addition to the requirements of Table 12.4.6, the range of the qualification of throat thickness of fillet welds, a, is given in Table 12.4.7. Where a fillet weld is qualified by a butt weld test, the throat thickness range qualified is to be based on the thickness of the deposited weld metal.
(d) The range of shielding gas compositions approved is to be in accordance with Table 11.9.2 in Chapter 11.
(e) A change in the brand or trade name of the filler metal from that used in the test is acceptable, provided that the proposed consumable has the same or higher strength grading.
(f) A change in post-weld heat treatment or ageing is not permitted, except that for the heat treatable alloys, artificial ageing may give approval for prolonged natural ageing.

Table 12.4.2 Acceptance criteria for internal imperfections of aluminium alloys

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2011	$d \leq$ 0,2*s* or 0,2*a* or 4 mm (whichever is the lesser)
Linear porosity (*see* Note 2)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	0,5*t* to 3*t* ≤ 1% of area > 3*t* to 12*t* ≤ 2% of area > 12*t* to 30*t* ≤ 3% of area > 30*t* ≤ 4% of area
Clustered porosity (*see* Note 1)	2013	*dA* ≤ 15 mm or *wp* (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	*l* ≤ 0,2*s* or 0,2*a* or 3 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	*l* ≤ 0,2*s* or 0,2*a* or 3 mm (whichever is the lesser)
Tungsten inclusion	3041	*l* ≤ 0,2*s* or 0,2*a* or 3 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed 0,2*t* or 0,2*a* (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size), in mm
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. For this acceptance criterion, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.

Table 12.4.3 Tensile strength requirements by grade for aluminium alloys

Parent material Grade (alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

Table 12.4.4 Welding procedure approval, welding positions for aluminium alloys

Test position		Positions approved
Downhand	D	D
Horizontal-vertical	X	D, X
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O

NOTE
Welding in vertical down (Vd) position is not recommended.

Table 12.4.5 Welding procedure approval, aluminium material grades approved

Material used in qualification test	Material Grades approved				
5754	5754				
5086	5086	5754			
5083	5083	5086	5754		
5383	5383	5083	5086	5754	
5059	5059	5383	5083	5086	5754
5456	5456	5383	5083	5086	5754
6005A	6005A	6082	6061		
6082	6005A	6082	6061		
6061	6005A	6082	6061		

NOTE
Approval includes all the different strained and tempered conditions in each case.

Table 12.4.6 Range of qualification for parent material thickness

Thickness of test assembly, t (mm)	Range of qualification Multi pass welds	Range of qualification All single-run or two-run (T technique) butt welds
$t \leq 3$	0,5 to 2t	0,5t to 1,1t
$3 < t \leq 20$	3 to 2t	0,5t to 1,1t
$t > 20$	≥ 0,8t	0,5t to 1,1t

Table 12.4.7 Range of qualification of throat thickness for fillet welds

Throat thickness of test piece, a (mm)	Range of qualification
$a < 10$	0,75 a to 1,5 a
$a \geq 10$	≥ 7,5

4.2 Requirements for copper alloys

4.2.1 The requirements for welding procedure qualification tests for copper alloys are to be in accordance with the requirements for steel as given in Section 2 with the following exceptions and additions.

4.2.2 Impact tests on copper alloys are not required.

4.2.3 Hardness tests are not required for seawater service.

4.2.4 For the welding of cast copper alloys for propellers, the minimum tensile strength from the transverse tensile test is to be in accordance with Table 12.4.8.

4.2.5 Bend tests are to be performed over a diameter of former as detailed in Table 12.4.9.

Table 12.4.8 Minimum transverse tensile strengths for welded copper alloy propellers

Alloy designation	Minimum tensile strength (N/mm^2)
CU 1	370
CU 2	410
CU 3	500
CU 4	550

4.2.6 The range of approval to be applied to the WPS is to be as specified in 2.15 with the exception of the material grades which are detailed in Table 12.4.10.

Table 12.4.9 Former diameters for bend testing of copper alloy welds

Alloy designation (*see* Chapter 9)	Former diameter (D/t)
Cast propellers: CU1 CU2 CU3 CU4	 4 4 6, *see* Note 6, *see* Note
Other short freezing range castings: Copper-Nickel 90/10 Copper-Nickel 70/30 Aluminium bronze	 4 4 6
Wrought alloys (tubes and pipes): Copper-phosphorus Aluminium-brass 90/10 Copper-nickel-iron 70/30 Copper-nickel-iron	 3 3 3 3
NOTE Where the qualification tests for these alloys are subjected to post-weld heat treatment the former diameter may be increased to D/t = 10.	

Table 12.4.10 Range of approval for copper alloy material grades

Category	Alloy grade used in the qualification test	Alloy grades approved
Propellers	CU1 CU2 CU3 CU4	CU1 CU1 and CU2 CU1, CU2 and CU3 CU4 *see* Note 1
Tubes/pipes	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron and 90/10 Copper-Nickel-Iron
Tubes/pipes *see* Note 2	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass
NOTES 1. Where a CU3 type welding consumable has been used for the qualification test, the range of approval may also include welding of CU3. 2. These grades have limited weldability and approval to weld is subject to the materials satisfying the requirements of Table 9.3.1 in Chapter 9.		

■ *Section 5*
Welder qualification tests

5.1 Scope

5.1.1 The requirements of this Section relate to qualification of welders involved in welded construction associated with ships, or other marine structures, and products or components intended for use on or in these structures.

5.1.2 The requirements relate to fusion welding processes that are designated as manual, semi-automatic or partly mechanised. Special consideration will be given to other welding processes adapted from these requirements.

5.1.3 Prior to commencing production welding, the welder is to have performed a qualification test that satisfies these requirements. It is the responsibility of the manufacturer to ensure that the welder possesses the required level of skill for the work to be undertaken.

5.1.4 The qualification of welders is to be documented by the manufacturer and the records are to be available for review by the Surveyor.

5.1.5 Welder qualification tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to, and meet the technical intent of these Rules to the satisfaction of the Surveyor.

5.2 Welder qualification test assemblies

5.2.1 The welding of the welder qualification test assembly is to simulate, as far as practicable, the conditions to be experienced in production and be witnessed by the Surveyor. The test is to be carried out on a test assembly piece and not by way of production welding.

5.2.2 The test is to simulate, as far as practicable, the welding techniques and practices to be encountered during production welding. The test assembly is to be designed to test the skill of the welder and have the shape and dimensions appropriate to the range of approval required.

5.2.3 The inspection length of the test weld is to be such as to permit the removal of all the necessary test specimens and for plate tests, but in no case is to be less than 250 mm. The test assembly is to be set in one of the positions as shown in Fig. 12.2.2 appropriate to the welding positions to be approved.

5.2.4 A welding procedure specification (WPS) is required for the execution of the qualification test and is to include the information specified in 2.2.1, as a minimum.

5.2.5 The test assembly is to be marked with a unique identification and the inspection length is to be identified prior to commencing welding. For pipe welds, the whole circumference is to be considered as the inspection length.

5.2.6 During welding of the test assembly, the welding time is to be similar to that expected under production conditions. For manual or semi-automatic processes, at least one stop and re-start in the root and in the top surface layer is to be included in the inspection length and marked for future inspection.

5.2.7 During welding of the test assembly, minor imperfections may be removed by the welder by any method that is used in production, except on the surface layer.

5.2.8 The Surveyor may stop the test if the welding conditions are not correct or if there is any doubt about the competence of the welder to achieve the required standard.

5.3 Examination and testing

5.3.1 Each completed test weld is to be examined and tested in accordance with the requirements of Table 12.5.1.

5.3.2 Visual examination is to be performed in the as welded state prior to any other assessment.

5.3.3 For plate butt welds, fracture testing may be used in place of radiography.

5.3.4 Where a backing strip has been used, it is to be retained for non-destructive examinations, but is to be removed prior to performing any bend or fracture tests.

5.3.5 Where fracture tests are required, they are to sample as much of the inspection length as practicable and the test assembly may be cut into several test specimens to achieve this. Testing is to be performed as shown in Figs. 12.5.1(a) or 12.5.1(b).

5.3.6 For butt weld tests in aluminium alloys both radiography and bend tests are required.

5.3.7 When bend tests are required, 2 root and 2 face bends are to be tested and where the test thickness exceeds 12 mm, these may be substituted by 4 side bends specimens. The diameter of former to be used is to be in accordance with that specified for welding procedure qualification testing given in 2.7.6(a).

5.3.8 Where macro examination is required, the specimen is to be polished and etched to reveal the weld runs and heat affected zones, and be examined at a magnification between x5 and x10.

Table 12.5.1 Welder qualification test requirements

Examination type	Butt welds	Fillet welds	Pipe branch welds
Visual	100%	100%	100%
Surface crack detection	*See* Note 1	100%	100%
Radiography	100% *See* Notes 2 and 6	Not required	Not required
Bend tests	4 required *See* Notes 3 and 6	Not required	Not required
Fracture tests	Not required	1 required *See* Note 4	Not required
Macro	Not required	1 required *See* Note 4	4 required *See* Note 5

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds 8 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.

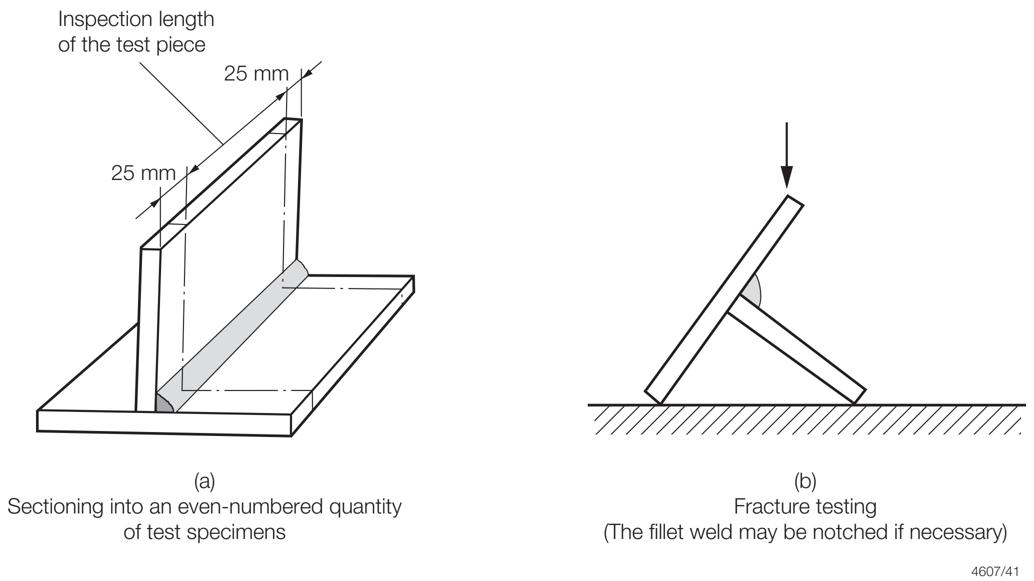


Fig. 12.5.1(a) Preparation and fracture testing of test specimens for a fillet weld in plate

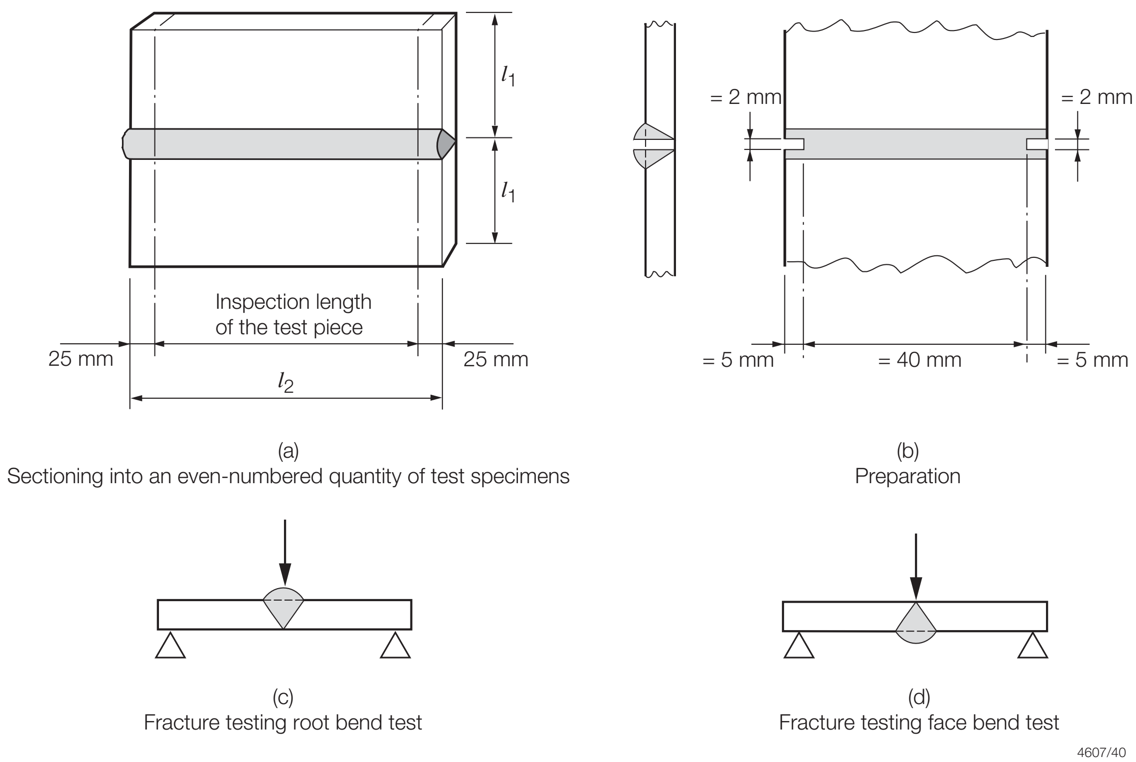


Fig. 12.5.1(b) Preparation and fracture testing of test specimens for a butt weld in plate

5.4 Acceptance criteria

5.4.1 The acceptance criteria are to be in accordance with 2.5.5.

5.4.2 Fracture tests and macro-sections are to be assessed in accordance with the non-destructive examination acceptance criteria.

5.4.3 Bend tests are considered acceptable if after bending through an angle of at least 180°, there are no defects on the tension side of the specimen greater than 3 mm in any direction.

5.5 Failure to meet requirements

5.5.1 Where a macro-section fails to meet requirements, one additional specimen may be removed from the test assembly and examined.

5.5.2 Where a bend or fracture test specimen fails to meet requirements, two additional specimens may be prepared from the same test assembly. If there is insufficient material, the welder may be permitted to weld an additional assembly to the same WPS, at the discretion of the Surveyor.

5.5.3 Where any of the additional test specimens fails to satisfy the requirements, the test will be considered as not meeting the requirements.

5.5.4 Where a test fails to comply with the acceptance criteria, the welder may be permitted to weld a second test piece. If this does not meet requirements, the welder is to be considered as not being capable of achieving the requirements.

5.6 Range of approval

5.6.1 Upon successful completion of all the necessary examinations and tests, the welder is to be considered qualified. The essential variables and the range of welding conditions for which the welder is considered approved are specified in the following paragraphs.

5.6.2 Welding variables such as preheat, interpass temperature, heat input and current type are not considered welder qualification variables. However, if the WPS used for testing specify these, they are to be included in the test and the welder is expected to follow the specific instructions.

5.6.3 Where the WPS used for the welder qualification test specifies post weld heat treatment, this need not be applied to the test weld unless bend tests are required and the material exhibits low ductility in the as welded condition.

5.6.4 The qualification test performed by a manufacturer is only applicable to workshops under the same technical control and quality system as that used for the test.

5.6.5 The welding process used in the qualification test is the process approved. However, it is possible for the welder to use more than one process in the test and the range of approval that may be applied to each will be within the limits of the essential variables appropriate to the part of the test where each welding process was used.

5.6.6 Material types are to be grouped as shown in Table 12.5.2 for welder qualifications. A qualification test performed on one material from a group will permit welding of all other materials within the same group. In addition, qualification on one group of materials may confer approval to weld other groups as shown in Table 12.5.3.

5.6.7 A qualification test performed on one thickness will confer approval to weld other thicknesses as specified in Table 12.5.4. Where welding is required between materials of different thickness, the reference thickness for approval purposes is to be the lesser thickness.

5.6.8 A qualification test performed on plate confers approval to weld on pipes having an outside diameter greater than 500 mm in a fixed position (*see* Table 12.5.5 and Table 12.5.6).

5.6.9 A qualification test performed using a specific diameter of pipe will give approval to weld other diameters as shown in Table 12.5.5. For branch welds, the diameter upon which approval is based is to be the branch member.

5.6.10 A qualification test performed on a butt weld may be considered as giving approval for fillet welds.

5.6.11 A butt qualification test welded from one side, with the root unsupported (i.e., no backing), will give approval for welds made from both sides with or without back gouging or grinding, but not vice versa.

5.6.12 A qualification test performed in one position will give approval to weld in other positions as shown in Table 12.5.6.

5.6.13 For manual metal arc welding with covered electrodes, a qualification test performed using an electrode with one type of coating will only be approved for welding with that type of coating. However, a qualification test performed using a basic low hydrogen type coating will confer approval to use electrodes with rutile coatings.

5.6.14 For gas shielded welding processes that use a single component shielding gas, no change to the gas composition is permitted from that tested. Where the test has used a two component shielding gas, a change in the ratio of component gases is permitted, provided that one of the components is not reduced to zero. Where the test has used a three component shielding gas, changes are permitted in the ratio of component gases and the gas with the smallest ratio may be reduced to zero, provided this does not change the shielding gas from an active one to an inert one or vice versa. In addition, where a change in shielding gas composition requires a different welding method or technique to be employed, a new qualification test will be required.

5.6.15 A change of welding flux from that used for the test is permitted.

Table 12.5.2 Welder qualification materials groupings

Material group	Material description	Typical LR Grades	Rules for Material references
WQ 01	Low carbon unalloyed, C/Mn, or Low alloyed steels (Re ≤ 360 N/mm^2)	A, B, D and E AH to FH32 and 36 Boiler 510FG and lower LT-AH to FH32 and 36 U1 and U2 Steel castings Steel pipes	Ch 3,2 Ch 3,3 Ch 3,4 Ch 3,6 Ch 3,9 and Ch 10 Ch 4,2, 3, 6 and 7 Ch 6,2, 3, 4 and 6
WQ 02	Cr-Mo, or Cr-Mo-V creep resisting steels	13CrMo45 and 11CrMo910 1Cr½Mo and 2¼Cr1Mo ½Cr½Mo¼V	Ch 3,4 Ch 4,6 and Ch 6,2, 3 and 6 Ch 4,6 and Ch 6,2
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2,0 – 5% Ni, with Re > 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1½ , 3½ Ni steels and castings U3, R3, R3S and R4	Ch 3,3 and 10 Ch 3,6 Ch 3,6, Ch 4,7 and Ch 6,4 Ch 3,9 and Ch 10
WQ 04	Ferritic, or martensitic stainless steels (12 to 20% Cr)	13% Cr (martensitic)	Ch 4,5 (martensitic)
WQ 05	Ferritic low temperature steels	5Ni and 9Ni	Ch 3,6
WQ 011	Ferritic-austenitic stainless steels, Austenitic stainless steels, or Cr-Ni steels	304, 316, 317, 321 and 347 S31260, S31803, S32550 and S32750	Ch 3,7 and 8 Ch 4,8 and Ch 6,5
WQ 22a	Aluminium alloy – Non-heat treatable Mg < 3,5%	5754	Chapter 8
WQ 22b	Aluminium alloy – Non-heat treatable 3,5% < Mg < 5,6%	5083 and 5086	Chapter 8
WQ 23	Aluminium alloy – Heat treatable	6005-A, 6061 and 6082	Chapter 8
WQ 30	Copper alloys for propellers – Manganese bronze	Cu1	Ch 9,1
WQ 31	Copper alloys for propellers – Nickel-manganese bronze	Cu2	Ch 9,1
WQ 32	Copper alloys for propellers – Nickel-aluminium bronze	Cu3	Ch 9,1
WQ 33	Copper alloys for propellers – Manganese-aluminium bronze	Cu4	Ch 9,1
WQ 34	Copper alloys for tubes – Copper phosphorus	Deoxidised – non-arsenical and arsenical	Ch 9,3
WQ 35	Copper alloys for tubes – Aluminium brass	Aluminium brass	Ch 9,3
WQ 36	Copper alloys for tubes – Copper-nickel-iron	70/30 Cu/Ni and 90/10 Cu/Ni	Ch 9,3

5.7 Welders qualification certification

5.7.1 All the relevant conditions used during the test are to be entered on the welder's qualification certificate along with the permitted range of approval.

5.7.2 If the Surveyor is satisfied that the welder has demonstrated the appropriate level of skill and all tests are satisfactory, the Surveyor will endorse the certificate verifying that the details contained on it are correct and that the test welds were prepared, welded and tested in accordance with the specified Rules, Codes or Standards.

5.7.3 The welder is considered to be approved for an initial validity period of 2 years. The welder is considered to have retained the qualification subject to the manufacturer confirming every 6 months that the welder has used the welding process with acceptable performance in the preceding 6 months.

5.7.4 After 2 years, the Surveyor may extend the validity of the approval for another period of two years provided that records or documented evidence is made available confirming acceptable welding performance, within the original range of approval, without a break exceeding 6 months. The Surveyor will signify acceptance of the extension to the validity by endorsing the certificate.

Table 12.5.3 Welder qualification, range of approval for material groups

Material group used for testing	Material groups approved to weld			
WQ 01	WQ 01			
WQ 02	WQ 01	WQ 02		
WQ 03	WQ 01	WQ 02	WQ 03	
WQ 04	WQ 01	WQ 02	WQ 04	
WQ 05	WQ 05			
WQ 11	WQ 11	WQ 05, *see* Note	WQ 04, *see* Note	
WQ 22a	WQ 22a	WQ 22b		
WQ 22b	WQ 22a	WQ 22b		
WQ 23	WQ 22a	WQ 22b	WQ 23	
WQ 30	WQ 30	WQ 31	WQ 32	WQ 33
WQ 31	WQ 30	WQ 31	WQ 32	WQ 33
WQ 32	WQ 30	WQ 31	WQ 32	WQ 33
WQ 33	WQ 30	WQ 31	WQ 32	WQ 33
WQ 34	WQ 34	WQ 35		
WQ 35	WQ 34	WQ 35		
WQ 36	WQ 36			

NOTE
Provided an austenitic welding consumable compatible with material group WQ 11 is used.

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \leq 3$ $3 < t \leq 12$ $t > 12$	t to $2t$ 3,0 to $2t$ ≥ 5,0
Aluminium alloys	$t \leq 6$ $6 < t \leq 15$ $t > 40$ mm	0,7 to $2{,}5t$ $6{,}0 < t \leq 40{,}0$ 41 to $2t$

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

Table 12.5.5 Welder qualification, diameter range of approval for pipes and hollow sections

Material type	Test piece diameter (mm)	Range approved (mm)
Steel and copper alloys	$D \leq 25$ $25 < D \leq 150$ $D > 150$ Plate, *see* Note 2	D to $2D$ $0{,}5D$ to $2D$, *see* Note 1 $\geq 0{,}5D$ ≥ 500
Aluminium alloys	$D \leq 125$ $D > 125$ Plate, *see* Note 2	$0{,}25D$ to $2D$ $\geq 0{,}5D$ ≥ 500

NOTES
1. Subject to 25 mm minimum diameter.
2. Plate qualification will approve welding on pipes greater than 150 mm diameter when the pipe is rotated.

Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
Type of weld	Test position	Plate		Pipe, *see* Note 1	
		Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt, *see* Note 5	D	D	D	D	D
	X	D,X	D, X	D	D, X
	Vu	D, Vu	D, X, Vu	D	D, Vu
	Vd	Vd	Vd	–	–
	O	D, X, Vu, O	D, X, Vu, O	D	D, X, Vu, O
Plate Fillet, *see* Note 5	D	–	D	–	D
	X	–	D, X	–	D, X
	Vu	–	D, X, Vu	–	D, X, Vu
	Vd	–	Vd	–	–
	O	–	D, X, Vu, O	–	D, X, Vu, O
Pipe butt	D	D	D, X	D	D, X
	X	D, X	D, X	D, X	D, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, Vu, O	D, X, Vu, O
	D+Vd+O, *see* Notes 2 and 3	Vd	Vd	Vd	Vd
	Axis at 45°, *see* Note 4, Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Notes 2, 3 and 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D	–	D	–	D
	X	–	D, X	–	D, X
	D+Vu+O *see* Note 3	–	D, X, Vu, O	–	D, X, Vu, O
	D+Vd+O *see* Note 3	–	Vd	–	Vd

NOTES
1. Pipe D position means pipe in horizontal position and rotated, *see* Fig. 12.2.2(b) and Fig. 12.2.2(d).
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests confers approval to weld pipes with diameter greater than 500 mm.

5.7.5 Where there is any reason to question the welder's ability, or there is a lack of continuity in the use of the welding process, or insufficient recorded evidence of acceptable weld performance, the welder is to perform a new qualification test.

5.7.6 Where the manufacturer has existing welders that have previously performed qualification tests, these may be considered for acceptance provided they satisfy the above requirements and the tests have been performed in the presence of an independent examiner that is acceptable to the Society.

5.7.7 Not withstanding the above, the Surveyor may at any time request a review of a welder's qualification records. If there is any reason for doubt concerning the skill of the welder, the Surveyor may withdraw the qualification and require a re-qualification test to be performed.

■ *Section 6* Qualification of friction stir welding of aluminium alloys

6.1 Scope

6.1.1 The requirements of this Section relate to the Friction Stir Welding (FSW) of aluminium alloys. These requirements include requirements for verification of welding equipment, welding procedures, qualification of welding procedures and qualification of welding operators.

6.2 Welding equipment

6.2.1 Welding equipment (e.g., welding machines and FSW tools) is to be capable of producing welds that meet the specified acceptance levels.

6.2.2 Welding equipment is to be maintained in a good condition and is to be repaired or adjusted when necessary.

6.2.3 After installation of new or refurbished equipment, appropriate tests are to be performed to verify that the equipment functions correctly.

6.3 Weld procedures

6.3.1 This Section defines the requirements for welding procedures to be applied for FSW of aluminium alloys.

6.3.2 Manufacturers are to prepare a preliminary welding procedure specification (pWPS) defining procedures for how FSW is to be conducted.

6.3.3 A pWPS is to comply with the requirements of ISO 25239-4.

6.3.4 Qualification of a pWPS is achieved by conducting weld procedure qualification tests in accordance with ISO 25239-4. Minimum acceptance criteria for destructive tests are to be in accordance with these Rules. Reporting of the qualification tests are to be in accordance with ISO 25239-4.

6.3.5 Provided that the procedure qualification record lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the procedure qualification record may be endorsed by the Surveyor as satisfying the requirement of the Rules.

6.3.6 A welding procedure specification (WPS) is to be prepared after the procedure qualification test report has been endorsed by the Surveyor.

6.3.7 For welding procedure specifications, the range of approval is to be limited as follows:

(a) **Manufacturer**. A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.
(b) **Range of material type**. Approval is restricted to the specific aluminium grade and supply condition used in the qualification test.
(c) **Thickness**. Approval is restricted to the thickness of the test piece in the qualification test.
(d) **Joint types**. The joint types approved are to be those from the welding procedure qualification test only.
(e) **Welding tool**. Approval is restricted to the specific design of welding tool employed during the qualification test.
(f) **Other**. A range of approval for any other variables will be subject to special consideration.

6.4 Qualification of welding operators

6.4.1 Welding operators are to be qualified in accordance with ISO 25239-3.

6.4.2 Welding operators are to be suitably trained and will be required to demonstrate a knowledge of FSW and have a working knowledge of the welding installation. Knowledge of the FSW process may be demonstrated by exams passed during the training period. Demonstration of a working knowledge of the welding installation will be subject to the Surveyor's satisfaction.

6.4.3 Qualification of welding operators is to be by welding tests as specified in ISO 25239-3 or by conducting weld procedure qualification tests.

6.4.4 Upon successful completion of all necessary examination and tests, the welding operator is to be considered qualified. The range of qualification is to be as specified in ISO 25239-3.

6.4.5 A certificate of qualification is to be issued in accordance with ISO 25239-3.

Section

■ *Section 1* General welding requirements

1.1 Scope

1.1.1 This Chapter specifies requirements for fabrication and welding during construction and repair of ships or other marine structures, and their associated pressure vessels, machinery, equipment, components and products intended for use in these structures.

1.1.2 The requirements for fabrication and welding during construction and repair of tanks intended for transport or storage of liquefied gases are located in the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* or the *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location*, as appropriate.

1.1.3 The requirements relate to fusion welding. Special consideration will be given to the use of other welding processes based on these requirements.

1.1.4 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules and inform the Surveyor of any deviations that have occurred. All deviations are to be recorded as non-compliances along with the corrective actions taken and failure to do this is considered to render the fabrication to be in non-compliance with the Rules.

1.1.5 Welded constructions that comply with National or International specifications may be accepted to the satisfaction of the surveyor, provided that these specifications give reasonable equivalence to the requirements of this Chapter.

1.1.6 All welded construction is to be to the satisfaction of the Surveyor.

1.2 Design

1.2.1 Prior to commencing any work, the component to be manufactured is to be subjected to design review and approval in accordance with the Rule requirements.

1.2.2 The material characteristics that are affected by welding, particularly the loss of strength (e.g., in precipitation or strain hardened aluminium alloys) are to be considered in the design. The weld joints in such materials are to be arranged such that they are in areas of lower stress.

1.3 Materials

1.3.1 Materials used in welded construction are to be manufactured at works approved by LR. The use of materials from alternative sources will be subject to agreement of the Surveyor and satisfactory verification testing.

1.3.2 Materials are to be supplied and certified in accordance with the requirements of Chapters 1 to 10 of these Rules.

1.3.3 Materials used in welded construction are to be readily weldable and are to have proven weldability, unless requirements are agreed with LR in advance.

1.3.4 Where the construction details are such that materials are subject to through-thickness strains, consideration is to be given to using material with specified through-thickness properties as specified in Ch 3,8.

1.3.5 When ordering materials for construction, consideration is to be taken of the possible degradation of properties during fabrication or post-weld heat treatment. Where these materials are used, consideration is to be given to additional test requirements being specified to the supplier.

1.3.6 The identity of materials is to be established by way of markings etc, during fabrication, so that traceability to the original manufacturer's certificate is maintained.

1.3.7 Pre-fabrication shop primers may be applied prior to welding, provided that they are of an approved type and have been tested to demonstrate that they have no deleterious effects on the completed weld.

1.3.8 Where it is proposed to weld forgings and/or castings, full details of the joint details, welding procedures and post-weld heat treatments are to be submitted for consideration.

1.4 Requirements for manufacture and workmanship

1.4.1 The welding workshops are to be assessed by the Surveyor for their capability to produce work of the required quality in accordance with the requirements specified for the type of construction, *see* Sections 2 to 5.

1.4.2 Where structural components are to be assembled and welded in works sub-contracted by the builder, the Surveyor is to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter is achieved.

1.4.3 The manufacturer is to provide a system of regular supervision of all welding, by suitably qualified and experienced personnel.

1.4.4 Welding is to be performed in covered workshops as far as practicable. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

1.4.5 Where required, arrangements are to be such as to permit adequate ventilation and access for preheating, and for the satisfactory completion of all welding operations.

1.4.6 The location of welding connections and sequences of welding are to be arranged to minimise distortion and the build up of residual stresses. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

1.4.7 In the case of repairs to existing structures or components, care is to be exercised when attaching fit-up aids by welding to ensure that the base materials in way of the attachments are of weldable quality.

1.4.8 In order to prevent cross-contamination of different material types, the welding of carbon steel materials is to be in areas segregated from that used for either austenitic or non-ferrous materials, *see* Section 7.

1.5 Cutting of materials

1.5.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

1.5.2 Cold shearing is not to be used on materials in excess of 25 mm thick. Where used, the cut edges that are to remain un-welded are to be cut back by machining or grinding for a minimum distance of 3 mm.

1.5.3 Material, which has been thermally cut, is to be free from excessive oxides, scale and notches.

1.5.4 All cut edges are to be examined to ensure freedom from material and/or cutting defects. Visual examination may be supplemented by other techniques.

1.5.5 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure no cracking. In these cases, the cut edge is to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

1.5.6 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal. Weld repair may only be performed with the agreement of the Surveyor.

1.6 Forming and bending

1.6.1 Plates, pipes, etc., may be formed to the required shape by any process which does not impair the quality of the material.

1.6.2 Where hot forming is employed or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.

1.6.3 As far as practicable, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition is not to be employed.

1.6.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the weld mechanical properties are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

1.7 Assembly and preparation for welding

1.7.1 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, corrective measures are to be adopted.

1.7.2 Provision is to be made for retaining correct alignment during welding operations in accordance with the approved manufacturing specifications and welding procedures.

1.7.3 Tack welds are to be avoided as far as practicable. When used, tack welds are to be of the same quality as the finished welds, made in accordance with approved welding procedures, and where they are to be retained as part of the finished weld, they are to be clean and free from defects.

1.7.4 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades. Smaller tack welds may be accepted for steels, provided that the carbon equivalent of the materials being welded is not greater than 0,36 per cent.

1.7.5 Where deep penetration welding is used (*see* 2.4.6), welding procedure tests are to demonstrate that the specified degree of penetration is achieved in way of tack welds left in place.

1.7.6 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and welded in accordance with approved welding procedures.

1.7.7 Any fit-up aids and tack welds, where welded to clad materials, are to be attached to the base material and not to the cladding.

1.7.8 Surfaces of all parts to be welded, are to be clean, dry and free from rust, grease, debris and other forms of contamination.

1.7.9 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and re-welded in accordance with an approved procedure.

1.8 Welding equipment and welding consumables

1.8.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking into account relevant safety precautions.

1.8.2 Suitable means of measuring the welding parameters (i.e. current, voltage and travel speed) are to be available. Electrical meters are to be properly maintained and have current calibrations.

1.8.3 Welding consumables are to be suitable for the type of joint and grade of material to be welded, and in general, are to be LR Approved in accordance with Chapter 11.

1.8.4 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in heated dry storage areas with a relatively uniform temperature in accordance with the consumable manufacturer's recommendations. Condensation on the metal surface (e.g., wire electrodes and studs) during storage and use is to be avoided.

1.8.5 Prior to use, welding consumables are to be dried and/or baked in accordance with the consumable manufacturer's recommendations.

1.8.6 Satisfactory storage and handling facilities for consumables are to be provided close to working areas and the condition of welding consumables are to be subject to regular inspections.

1.9 Welding procedure and welder qualifications

1.9.1 Welding procedures are to be developed by the manufacturer for all welding, include weld repairs, and are to be capable of achieving the mechanical property requirements and non-destructive examination quality appropriate to the work being undertaken.

1.9.2 Welding procedures are to be established for the welding of all joints and are to be qualified by testing in accordance with Chapter 12. The welding procedures are to give details of the welding process, type of consumable, joint preparation, welding position and filler metals to be used.

1.9.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

1.9.4 All welders and welding operators are to be qualified in accordance with the requirements of Chapter 12. Qualification records to demonstrate that welding personnel have the skills to achieve the required standard of workmanship are to be available to the Surveyor.

1.10 Welding during construction

1.10.1 Materials to be assembled for welding are to be retained in position by suitable means such that the root gaps and alignment are in accordance with the approved manufacturing specifications and welding procedures.

1.10.2 Surfaces of all parts to be welded, are to be clean, dry and reasonably free from rust, scale and grease.

1.10.3 Pre-heat is to be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level throughout the welding operation.

1.10.4 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care is to be taken to pre-heat the joint to a minimum of 20°C, unless a higher pre-heat temperature is specified.

1.10.5 Where tack welds are to be removed from the root of the weld joint, this is to be carried out such that the surrounding material and joint preparation is not damaged.

1.10.6 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

1.10.7 Where the welding process used is slag forming (e.g., manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

1.10.8 Full penetration welds are to be made from both sides of the joint as far as practicable. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

1.10.9 Where welding from one side only, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

1.10.10 Particular care is to be exercised in welding in the vertical position with direction of travel downward (Vd) to avoid welding defects. The use of solid wire gas metal arc (GMAW) process in the vertical down position is to be avoided.

1.10.11 Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption.

1.10.12 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

1.10.13 Care is to be taken to avoid stress concentrations such as sharp corners or abrupt changes of section, and completed welds are to have an even contour, blending smoothly with the base materials. The weld shape and size is to be in accordance with that specified in the approved drawings or specifications.

1.10.14 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

1.10.15 Where fabricated and welded components require to be machined, all major welding operations are to be completed prior to final machining.

1.10.16 Welding to parts which are subjected to rotating fatigue (e.g., shafts) is not generally permitted.

1.10.17 Welding onto parts that have been hardened for wear resistance or strength (e.g., gear teeth) is not permitted.

1.10.18 Where welding of clad ferritic steel plates is to be undertaken, the clad materials are to be ground back from the prepared edge by at least 10 mm. In general, the ferritic materials are to be welded prior to welding of the cladding material.

1.11 Non-destructive examination of welds

1.11.1 Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to Level III qualification of ISO 9712, SNT-TC-1A, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be reviewed by the Surveyor. *See* Ch 1,5.

1.11.2 Non-destructive examinations are to be undertaken by personnel qualified according to a Nationally Recognised Scheme with a grade equivalent to Level II qualification of ISO 9712, SNT-TC-1A or ASNT Central Certification Program (ACCP). Operators qualified to Level I of the above schemes (or equivalent recognised by LR) may be engaged in testing under the supervision of personnel qualified to Level II or III (or equivalent recognised by LR). Personnel qualifications are to be verified by certification.

1.11.3 Effective arrangements are to be provided by the manufacturer for the inspection of finished welds to ensure that all welding, and where necessary, all post-weld heat treatment, has been satisfactorily completed.

1.11.4 Welds are to be clean and free from paint at the time of visual inspection unless specified otherwise in the following Sections.

1.11.5 The weld surface finish is to ensure accurate and reliable detection of defects. Where the weld surface is irregular or has other features likely to interfere with the interpretation of non-destructive examination, the weld is to be ground or machined.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired and re-inspected.

1.11.7 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

1.11.8 Non-destructive examinations are to be performed in accordance with the requirements of the Rules. Examinations are to be in accordance with agreed written procedures prepared by the manufacturer or ship builder.

1.11.9 The Surveyor may request additional inspections where there is reason to question the quality of workmanship, or where the weld is part of a complicated fabrication where there is high restraint or high residual stresses.

1.11.10 Welds are to be examined after completion of any post-weld heat treatment.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter. The repairs are to be re-inspected using the same technique as the original inspection.

1.11.12 Results of non-destructive examinations are to be recorded and evaluated by the constructor on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

1.11.14 The extent of applied non-destructive examination is to be increased when warranted by the analysis of previous results.

1.12 Routine weld tests

1.12.1 Routine or production weld tests may be specified as a means of monitoring the quality of the welded joints. This type of quality control test is generally specified for pressure vessel and LNG construction but may be used for other types of welded fabrication.

1.12.2 Routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

1.12.3 Where routine test welds have been agreed, they are to be performed in accordance with the general requirements for the type of construction, *see* Sections 3 and 4.

1.13 Rectification of material defects

1.13.1 Repair of defects found in base materials is not to be carried out without the prior approval of the Surveyor.

1.13.2 In general, surface defects in the material may be removed by grinding, chipping, etc., provided the remaining material thickness is not reduced below the minimum thickness tolerance, and the area is ground to blend in smoothly with the surrounding material.

1.13.3 Confirmation that the defect has been removed is required by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.13.4 Surface defects, which cannot be repaired by the above method, may be repaired by welding where permitted by Chapters 3 to 9. Such repairs are to be performed in accordance with the requirements of this Section and those specified in Chapters 3 to 9.

1.13.5 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

1.14 Rectification of distortion

1.14.1 Fairing, by linear or spot heating, to correct distortions due to welding, may be carried out. In order to ensure that the properties of the material are not adversely affected, approved procedures are to be utilised. On completion of such processes, visual examination of all heat affected areas in the vicinity is to be carried out to ensure freedom from cracking.

1.14.2 When misalignment of members exceeds the agreed tolerance, the misaligned item is to be cut apart, realigned and re-welded in accordance with an approved procedure.

1.15 Rectification of welds defects

1.15.1 Where repairs are extensive the manufacturer is to investigate the reason for the defects and take the necessary actions to prevent recurrence. In addition, consideration is to be given to the sequence of repairs and to providing temporary supports to prevent misalignment or collapse.

1.15.2 Cracks are to be reported to the Surveyor and the cause established prior to undertaking weld repairs.

1.15.3 Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove is to be subsequently ground clean to remove oxides and debris. The groove is to have a profile suitable for welding.

1.15.4 Prior to commencing repair welding, it is to be confirmed that no defect exists on the prepared surface by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.15.5 Repair welding is to be performed using approved welding procedures.

1.15.6 Completed repairs are to be re-examined by the non-destructive examination method(s) that detected the original defect and are to confirm that the original defect has been removed.

1.15.7 Where the component or structure has been subjected to post-weld heat treatment prior to weld repair, this is to be repeated after completion of all repair welding.

1.15.8 Where non-destructive examination reveals that the original defect has not been successfully removed, one more repair attempt may be performed.

1.15.9 The manufacturer is to monitor the quality of welding and maintain records of welding repairs and take the necessary corrective actions where repair rates are outside normal limits.

1.16 Post-weld heat treatment

1.16.1 On completion of welding, post-weld heat treatment may be required depending on the type of welded construction, the material type and thickness as specified by the relevant Parts or Sections of the Rules.

1.16.2 In general, heat treatment after welding is to be a stress relief treatment in order to reduce residual stresses introduced by welding and is generally applicable to ferritic steels. Where other types of heat treatment (e.g., normalising, solution annealing) are proposed, demonstration of acceptable mechanical properties of the weldment are to be confirmed by a welding procedure test which includes a simulated heat treatment.

1.16.3 Parts are to be properly prepared for heat treatment. Machined surfaces (e.g., flange faces, screw threads, etc.) are to be protected against scaling and sufficient temporary supports provided to prevent distortion or collapse of the structure.

1.16.4 Details of the heat treatment to be applied, soaking time and temperature, heating and cooling rates, etc., are to be submitted for review prior to commencing.

1.16.5 Post-weld heat treatment is to be carried out in a purpose built furnace which is efficiently maintained. In special cases, where the configuration of the component is such that thermal stresses during heating and cooling can be minimised, local post-weld heat treatment may be used. This would not normally apply to the complex geometry of cast materials during manufacture within the foundry environment.

1.16.6 In all cases, the heat treatment facilities and arrangements are to be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the component temperature are to be provided. Thermocouples are to be attached so they are in contact with the component.

1.16.7 Unless specified otherwise, stress relief heat treatment is to be carried out by means of controlled heating from 300°C, to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually 1 hour per 25 mm of weld thickness) followed by controlled cooling to below 300°C.

1.16.8 Where post-weld stress relief is specified for welded constructions that contain joints between different materials (e.g. ferritic to austenitic steels), the details of the materials, welding procedures and heat treatment cycle to be applied are to be submitted for special consideration and approval.

1.16.9 Non-destructive examination of welds is to be performed after completion of any heat treatment.

1.17 Certification

1.17.1 Products or components are not to be considered complete until all the requirements of the construction specification have been met and all activities have been completed.

1.17.2 Upon completion of the works, the manufacturer is to provide documentation which indicates that:

(a) All welds are complete and there are no outstanding repairs.
(b) The appropriate post-weld heat treatments have been performed.
(c) Appropriate destructive tests have been performed.
(d) Proof testing of welds has been performed.

1.17.3 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product is in accordance with the requirements of 1.17.2.

■ *Section 2* Specific requirements for ship hull structure and machinery

2.1 Scope

2.1.1 The requirements of this Section apply to the construction of ships, including hull structure, superstructure and deckhouses, components forming part of the ship structure and its machinery (excluding pressure equipment and piping, *see* Section 4). These requirements are in addition to the general welding requirements specified in Section 1.

2.1.2 The shipyard and manufacturer's works are to be assessed to give assurance that they have the facilities, equipment, personnel and quality control procedures to produce work of the required quality.

2.2 Welding consumables

2.2.1 Welding consumables used for hull construction are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of material to be welded.

2.2.2 Steel welding consumable approvals, up to and including Grade Y40 and Y47, are considered acceptable for hull construction in line with Table 11.1.1 in Chapter 11, Ch 12,2.2.2 and the following:

(a) Consumables up to Grade Y are acceptable for welding steels up to 3 strength levels below that for which the approval applies, e.g., a consumable with approval grading 3Y is acceptable for welding EH36, EH32 and EH27S higher tensile ship steels and grade E normal strength ship steel.
(b) Consumables for Grade Y40 are acceptable for welding steels up to two strength levels below that for which the approval applies. Consumables for Grade Y47 are acceptable for welding steels up to one strength level below that for which the approval applies.
(c) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) above, e.g. a consumable with approval grading 3Y is acceptable for welding EH, DH and AH materials.
(d) For welding steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

2.2.3 In general, the use of preheating and hydrogen controlled welding consumables for welding of ship steels up to strength grade H40 is to be in accordance with Table 13.2.1. The carbon equivalent is to be calculated from the ladle analysis using the formula given below:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Preheat and the use of low hydrogen controlled consumables will be required for welding of steel grades higher than Grade H40.

Table 13.2.1 Preheat and consumable requirements for welding of carbon and carbon manganese steels up to strength grade H40

Carbon equivalent C_{eq}	Pre-heat	Hydrogen controlled consumables
C_{eq} equal to or less than 0,41%	Not required	Not required, *see* Note 3
C_{eq} above 0,41 but not exceeding 0,45%	Not required, *see* Notes 1 and 2	Required
C_{eq} greater than 0,45%	Required	Required

NOTES
1. Preheat may need to be applied in order to meet the maximum hardness values specified in Ch 12,2.12.6.
2. Under conditions of high restraint or low ambient temperature preheat may need to be applied.
3. Hydrogen controlled consumables may need to be considered for welding of
   (a) Thicker materials (i.e., > 35 mm).
   (b) Higher strength materials.
   (c) Welds subject to high restraint.

2.2.4 All aluminium alloy welding consumables are to be approved in accordance with Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.2.

Table 13.2.2 Welding of aluminium alloys – Consumable requirements

Consumable approval grade	Base material alloy grade
RA or WA	5754
RB or WB	5086, 5754
RC or WC	5083, 5086, 5754
RD or WD	6005A, 6061, 6082

2.2.5 All austenitic stainless steel and duplex stainless steel welding consumables are to be approved in accordance with the Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.3.

2.3 Welding procedure and welder qualifications

2.3.1 Welding procedures and welder qualifications are to be tested and approved in accordance with the requirements of Chapter 12.

2.4 Construction and workmanship

2.4.1 Weld preparations and openings may be formed by thermal cutting, machining or chipping. Chipped surfaces that will not be subsequently covered by weld metal are to be ground smooth.

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steels	
321	321
347	347 and 321
Austenitic stainless steel – Low carbon	
304L (*see* Note 3)	304L
304LN (*see* Note 3)	304LN and 304L
316L	316L and 304L
316LN	316LN, 316L, 304LN and 304L
317L	317L, 316LN, 316L, 304LN and 304L
317LN	317LN, 317L, 316LN, 316L, 304LN and 304L
Super austenitic stainless steels, *see* Note 2	
S31254	S31254 and N08904
N08904	N08904
Duplex stainless steels, *see* Note 1	
S31260	S31260 and S31803
S31803	S31803
S32550	S32550
S32750	S32750 and S32550
S32760	S32760, S32550, S31260 and S31803
Stainless steels welded to carbon steels	
SS/CMn	Carbon steel to all steels in Sections 1, 2 and 3
Duplex/CMn	Carbon steel to all duplex stainless steel in Section 4

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.
3. These are LR Grades and do not correspond to any National or International Standards/Grades.

2.4.2 Prior to welding, the alignment of plates and stiffeners forming part of the hull structure is to be in accordance with the tolerances specified in the relevant part of the Rules.

2.4.3 When welding from one side only, care is to be exercised to ensure the root gap and fit up are in accordance with the approved welding procedure and the root is properly fused.

2.4.4 Where it is proposed to use permanent backing strips, the intended locations and welding procedures are to be submitted for consideration.

2.4.5 Temporary backing strips may be used provided they are in accordance with approved welding procedures and are subsequently removed on completion of welding.

2.4.6 The outer surfaces of completed welds are to blend smoothly with the base materials and provide a smooth transition and gradual change of section.

2.4.7 Weld joints in parts of oil engine structures that are stressed by the main gas or inertia loads are to be designed as continuous full penetration welds. They are to be arranged so that welds do not intersect, and that welding can be effected without difficulty.

2.4.8 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.4.9 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with so far as they are applicable:

(a) Welding is to be performed by fusion welding using inert gas or tungsten inert gas process or by the friction stir welding process. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The weld joint surfaces should be scratch brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, filings, etc.

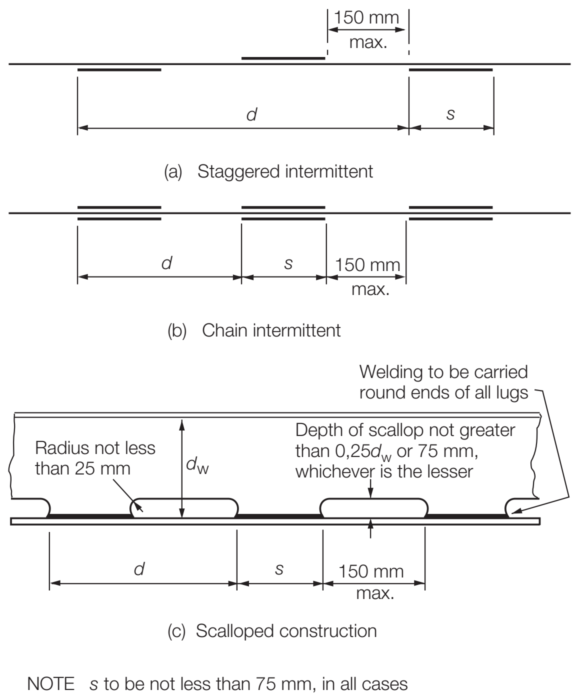


Fig. 13.2.1 Weld types

2.5 Butt welds

2.5.1 Where the ship hull is constructed of plates of different thicknesses, the thicker plates are to be chamfered in accordance with the approved plans. In all cases the chamfer is not to exceed a slope of 1 in 3 so that the plates are of equal thickness at the weld seam. Alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate provided the difference in thickness is not greater than 3 mm.

2.5.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these are to be made flush in way of the fillet weld. Similarly for butt welds in webs of stiffening members, the butt weld is to be complete and generally made flush with the stiffening member before the fillet weld is made. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member, *see* Fig. 13.2.1. Scallops are to be of such a size and in such a position that a satisfactory weld can be made.

2.6 Lap connections

2.6.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. However, where plate overlaps are adopted, the width of the overlap is not to exceed four times, nor be less than three times the thickness of the thinner plate and the joints are to be positioned to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

2.7 Closing plates

2.7.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to be smooth and clean and are to be spaced not more than 230 mm apart, centre to centre. Slots are not to be filled with welding.

2.7.2 For the attachment of rudder shell plating to the internal stiffening of the rudder, slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded and the space between them is not to exceed 150 mm.

2.8 Stud welding

2.8.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be approved.

2.9 Fillet welds

2.9.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 13.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

2.9.2 Where an approved deep penetration procedure is used, the fillet leg length calculated may be reduced by 15 per cent provided that the manufacturer is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 11 for either the ‘p’ or ‘T’ techniques.
(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e., throat thicknesses) are maintained. This is to be documented on a monthly basis by the manufacturer and be available to the Surveyor.

2.9.3 The calculated fillet leg length may be reduced by 20 per cent, provided that in addition to the requirements of 2.9.2(a) and (b), the manufacturer is able to consistently meet the following additional requirements:

(a) The documentation required in 2.9.2(b) is to be completed and made available to the Surveyor upon request on a weekly basis.
(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.9.4 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at orthogonal connections with other members.

2.10 Post-weld heat treatment

2.10.1 Post-weld stress relief heat treatment is applied to improve the fatigue performance or to improve resistance to brittle fracture and is generally required for carbon and carbon-manganese and low alloy steels under any of the following conditions:

(a) Where the material thickness exceeds 65 mm.
(b) For complicated weld joints where there are high stress concentrations.
(c) Where fatigue loads are considered high.

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm, except where castings are directly welded to the hull structure.
(b) Oil engine bedplates except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need to be stress relieved.
(c) Welding of gear wheels.
(d) Welding of gear cases associated with main or auxiliary engines, *see* Part 5 of the Rules for Ships.

2.10.3 Where required, heat treatment is to be performed in accordance with the requirements specified in 4.6 for pressure vessel construction.

2.10.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on critical engineering assessment involving fracture mechanics testing and proposals are to be submitted which include full details of the application, materials, welding procedures, inspection procedures, design stresses, fatigue loads and cycles. Evidence will be required to demonstrate that the inspection techniques and procedures to be employed are able to detect flaws down to the sizes determined from the fracture mechanics (and or fatigue) calculations. Alternative procedures for omission of post-weld heat treatment will be subject to special consideration.

2.11 Tolerances

2.11.1 Tolerances after welding are to be in accordance with the relevant Part of the Rules.

2.11.2 Distortion which has resulted from welding may be corrected by spot heating in accordance with 1.14.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds is avoided.

2.12.2 Welds forming part of the hull and superstructure may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.12.3 All welds are to be visually inspected by personnel designated by the builder. Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary. The acceptance criteria for visual testing are given in Table 13.2.4.

2.12.4 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

Table 13.2.4 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria for visual testing
Crack	100	Not accepted
Lack of fusion	401	Not accepted
Incomplete root penetration in butt joints welded from one side	4021	Not accepted
Surface pore	2017	Single pore diameter $d \leq 0{,}25t$, for butt welds, with maximum diameter 3 mm, *see* Note 1 $d \leq 0{,}25a$, for fillet welds, with maximum diameter 3 mm, *see* Note 1 2,5d as minimum distance to adjacent pore
Undercut in butt welds	501	Depth ≤ 0,5 mm, whatever the length Depth ≤ 0,8 mm, with a maximum continuous length of 90 mm, *see* Note 2
Undercut in fillet welds	501	Depth ≤ 0,8 mm, whatever the length

NOTES
1. t is the plate thickness of the thinnest plate, and a is the throat of the fillet weld.
2. Adjacent undercuts separated by a distance shorter than the shortest undercut are to be regarded as a single continuous undercut.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of 8 mm thickness or less. Ultrasonic testing is acceptable for welds of 8 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration. Advanced ultrasonic techniques, such as Phased Array Ultrasonic Testing (PAUT), may be used as a volumetric testing method in lieu of radiography or manual ultrasonic testing. If these methods are used, the thickness limitations for manual ultrasonic testing apply.

2.12.6 The acceptance criteria for radiographic testing are given in Table 13.2.5, and those for ultrasonic testing in Table 13.2.6.

2.12.7 Checkpoints examined at the pre-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspection of weld ends.

2.12.8 Checkpoints examined at the assembly stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the builder. The locations and number of checkpoints are to be approved by the Surveyor.

2.12.9 Where components of the structure are subcontracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the main contractor's works. In these cases, particular attention is to be given to highly loaded fabrications (such as stabiliser fin boxes) forming an integral part of the hull envelope.

2.12.10 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at stern frame connections.

2.12.11 Special attention is to be given to the examination of plating in way of lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed, but includes the positions where lifting eye plates are permanent fixtures.

2.12.12 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.12.13 Typical locations for volumetric examination and number of checkpoints to be taken are given in the relevant Sections of the Rules. A list of the proposed items to be examined is to be submitted for approval.

2.12.14 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships *see* the *Rules for the carriage for Liquefied Gases*.

2.12.15 For all ship types, the builder is to carry out random non-destructive examination at the request of the Surveyor.

2.12.16 Results of non-destructive examinations made during construction are to be recorded and evaluated by the builder on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

2.12.17 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length $t/2$ or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum t or 50 mm, whichever is less, *see* Note 3
Lack of root fusion	4013	Not accepted in butt joints welded from one side
Incomplete root penetration	4021	Not accepted in butt joints welded from one side
		Continuous maximum length $t/2$ or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length t or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length t or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum $2t$ or 100 mm, whichever is less, *see* Notes 3 and 4
Gas pore	2011	Maximum dimension for a single pore: $d \leq 0{,}2t$, max. 4,0 mm *see* Note 5
Uniformly distributed porosity	2012	Maximum dimension of the area of imperfections: For single run welds: ≤ 1,5% For multi-run welds: ≤ 3% *See* Notes 6 and 7
Clustered (localised) porosity	2013	Maximum dimension of the summation of the projected area of the imperfection: ≤ 8% *See* Notes 6 and 7
Elongated cavity	2015	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Wormholes	2016	$h \leq 0{,}3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Metallic inclusions other than copper	304	$h \leq 0{,}3t$, max. 3,0 mm *See* Note 8
Copper inclusions	3042	Not permitted

NOTES
1. t is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length l_d1 and l_d2 situated on a line and where the distance l_d between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length $l_d1 + l_d + l_d2$.
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.
5. d is the diameter of the gas pore.
6. The limits for the maximum single gas pore within this group still apply.
7. Further reference to porosity limits may be obtained in ISO 5817:2007.
8. h is the width of the imperfection.
9. l is the length of the imperfection.

2.13 Weld repairs

2.13.1 The full extent of any weld defect is to be ascertained by applying additional non-destructive examination where required. Unacceptable defects are to be completely removed and, where necessary, re-welded and re-examined in accordance with the requirements of 1.15.

2.13.2 During the assembly of large components, root gaps in excess of those specified in the approved welding procedure may be rectified by welding.

Table 13.2.6 Acceptance criteria for ultrasonic testing

Echo height	Acceptance criteria for ultrasonic testing, *see* Note
Greater than 100% of DAC curve	Maximum length t/2 or 25 mm, whichever is less
Greater than 50% of DAC curve, but less than 100% of DAC curve	Maximum length t or 50 mm, whichever is less
Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration or lack of root fusion in joints welded from one side are unacceptable regardless of echo height.	
NOTE Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1 + L + L2.	

2.13.3 Rectification of wide root gaps in butt welds, up to a maximum gap of 16 mm, may be performed provided that the length of these areas is small in relation to the whole weld length. Repairs may be executed by applying weld buttering layers to one edge of the weld joint, followed by machining or grinding to return the root opening to the required dimensions. The weld buttering and filling of the joint are to be in accordance with welding procedures qualified in accordance with Chapter 12.

2.13.4 For sub-assemblies, rectification of wide root gaps may be performed using a backing strip, provided that it is removed on completion of the welding.

2.13.5 Rectification of wide root gaps in fillet welds may be carried out as follows:

(a) where the root gap, g, is in excess of 3 mm, but not greater than 5 mm, the fillet leg length, z, may be increased by g – 2,0 mm;
(b) where the root gap is in excess of 5 mm, the joint detail may be changed into a full penetration weld.

2.13.6 Where repair welds are made using small weld beads, suitable precautions (including preheat) are to be taken to avoid high hardness and possible cold cracking.

2.14 Welding afloat with water backing

2.14.1 Welding afloat with water backing is not recommended due to the additional precautions required during survey and therefore, is generally not permitted. However consideration may be given to welding afloat with water backing after specific LR approval has been obtained by the yard or fabricator prior to such welding being carried out. Such approval will only be given once all of the following conditions are satisfied:

(a) The welding procedure qualification tests are carried out on steel plates with water backing and the water is maintained at the flow rate and minimum water temperature anticipated during fabrication.
(b) The carbon equivalent of the steel plates used in the welding procedure qualification tests are to be greater than 0,41 per cent based on the IIW formula. Where it can be shown that all hull steel plates and new sections will have a carbon equivalent value below this figure, steel plates with the maximum carbon equivalent value may be used for the welding procedure qualification tests.
(c) Welding procedure qualification tests are carried out without preheat.
(d) The thickness of steel plate used in the welding procedure qualification test is the minimum hull plate thickness to be used during fabrication.
(e) The maximum measured hardness on the completed welding procedure qualification assembly is less than or equal to 350 HV10. Following fabrication welding, 10 per cent of welds are to be hardness tested in way of heat-affected zones at weld starts to confirm compliance with the 350 HV10 limit.
(f) The heat input used in the welding qualification test is the minimum permitted heat input during fabrication.
(g) Only low hydrogen welding consumables (H5) are used.
(h) In addition to normal non-destructive testing for welds, 10 per cent of the welds are additionally subject to magnetic particle inspection 48 hours after welding is complete.
(j) The welding procedure qualification tests for the repair of welds carried out afloat with water backing are to be carried out on test pieces that have previously been welded afloat and also meet the requirements above.

2.14.2 For new construction, conversion or permanent repairs, wet underwater welding is not permitted.

■ *Section 3* Specific requirements for fabricated steel sections

3.1 Scope

3.1.1 Fabricated steel sections are items used in place of rolled sections and as such will not be regarded as sub-assemblies. Products regarded as sub-assemblies are subject to requirements of welded construction specified in Section 2.

3.1.2 The requirements for structural steel sections are based on these being manufactured from flat products by automatic welding and intended for use in the construction of ships and other marine structures.

3.1.3 Fabricated steel sections are to be manufactured in accordance with the requirements of this Section and the general requirements of Section 1.

3.1.4 In all cases, sections are to be manufactured at works, which have been assessed and approved in accordance with *Materials and Qualification Procedures for Ships, Book J, MQPS Procedure 12-1*.

3.2 Dimensions and tolerances

3.2.1 Products are to conform dimensionally to the provisions of an acceptable National or International Standard.

3.2.2 The minimum throat thickness of fillet welds is to be determined from:

Throat thickness = 0,34t but not to be taken as less than 3 mm

where

t = plate thickness of the thinner member to be joined (generally the web).

3.2.3 Where a welding procedure using deep penetration welding is used (*see* Chapter 11, 'p' and 'T' welding techniques) the minimum leg length required will be specially considered provided the requirements of 2.9.2 are complied with.

3.2.4 Unless agreed otherwise, the leg length of the weld is to be not less than 1,4 times the specified throat thickness.

3.3 Identification of products

3.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with the following particulars:

(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) Where required by the purchaser, the order number or other identification mark.
(e) The letters 'LR'.
(f) The Surveyor's personal stamp.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be removed or unmistakably defaced, *see also* Ch 1,4.7.

3.4 Manufacture and workmanship

3.4.1 For cut edges that are to remain unwelded, it is to be demonstrated that the plate preparation procedures used are able to achieve edges that are free from cracks or other deleterious imperfections.

3.4.2 Where assembly jigs and devices are used to bring the web into contact with the flanges and hold these in place during welding, means are to be provided to ensure that the degree of contact is maintained until welding is complete.

3.4.3 Welding procedures are to be established for the welding of all joints including weld repairs and are to be approved in accordance with Chapter 12. Welders are to be approved in accordance with Chapter 12, and qualification records are to be available to the Surveyor.

3.4.4 The welding consumables used are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of steel as described in 2.2. For joining steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

3.4.5 The application of pre-heat and the use of low hydrogen welding consumables are to be in accordance with the requirements of 2.2.

3.4.6 Welding is to be double continuous fillet welding or full penetration welding as specified in the approved plans.

3.4.7 Where deep penetration welding is used, the requirements of 2.9.2 are to be complied with.

3.5 Non-destructive examination

3.5.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all materials prior to despatch. Acceptance by the Surveyor of material later found to be defective does not absolve the manufacturer from this responsibility.

3.5.2 The Surveyor will carry out checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures.

3.5.3 The manufacturer is to examine the welds by magnetic particle or dye penetrant methods. The length examined is to be 200 mm at each end, for each length cut for delivery.

3.5.4 If cracks are revealed, these are to be reported to the Surveyor and the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process, and repairs are to be as indicated in the manufacturers' Quality Control Manual.

3.5.5 The weld defect is not to exceed the acceptance levels given in Table 13.2.4.

3.6 Routine weld tests

3.6.1 One production batch test is required for every 500 m of fabricated section manufactured, or fraction thereof. From each batch test, two samples are to be removed, one from near the beginning of the production run and one from near the end. From each of these test samples one macro specimen and one fracture test specimen are to be taken.

3.6.2 The macro specimens are to be prepared and etched to demonstrate freedom from unacceptable defects and that the weld penetration is in accordance with the manufacturing specification. The fracture specimens are to be broken, one for each side of the fillet weld, and the fractured surfaces examined for compliance with the requirements of Table 13.2.5.

3.6.3 Where the welding procedure used has employed the deep penetration technique, the amount of root penetration is to be measured on the macro specimen and is not to be less than that demonstrated during welding procedure approval testing.

3.6.4 For the purposes of this Section, a batch is to consist of products of only one size and grade of material.

3.7 Certification and records

3.7.1 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Where known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates.
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

3.7.2 Test certificates or shipping statements may be signed by the Surveyor, provided the documentation requirements of 1.17 are satisfied. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved procedure in accordance with the Lloyd's Register's Rules for Materials'.

3.7.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections and tests.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.1 Scope

4.1.1 The requirements of this Section apply to fusion welded pressure vessels and process equipment, heating and steam raising boilers, and steam or gas turbine rotors and cylinders and are in addition to those requirements referred to in Section 1.

4.1.2 The allocation of pressure vessel Class is determined from the design criteria in Pt 5, Ch 10 and 11 of the Rules for Ships. Prior to commencing construction, the design of the vessel is to be approved. Construction requirements for turbine rotors and cylinders are to be in accordance with Class 2/1, unless a higher Class is specified in the approved plans.

4.1.3 Pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding work required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

4.1.4 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic, or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes.

4.2 Cutting and forming of shells and heads

4.2.1 Cut or chipped surfaces which will not be subsequently covered by weld metal are to be ground smooth.

4.2.2 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

4.2.3 Vessels manufactured from carbon or carbon manganese steel plates (*see* Table 3.4.1 in Chapter 3, grades 360AR to 510FG), which have been hot formed or locally heated for forming, are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition are to be heat treated in accordance with the material manufacturer's recommendations.

4.2.4 Subsequent heat treatment will not be required where steels are supplied in the as-rolled, normalised or normalised and controlled rolled condition, or hot forming is carried out entirely at a temperature within the normalising range.

4.2.5 For alloy steel vessels where hot forming is employed (*see* Table 3.4.1 in Chapter 3, 13Cr Mo 45, etc.), the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

4.2.6 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

4.2.7 In all cases where hot forming is employed, and for cold forming to a radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

4.3 Fitting of shell plates and attachments

4.3.1 The location of welded joints is to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

4.3.2 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the misalignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

4.3.3 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

4.3.4 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

4.3.5 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

4.3.6 All attachments (lugs, brackets, reinforcing plates, etc.) are to conform to the shape of the surface to which they are attached.

4.4 Welding

4.4.1 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts. Welding procedures are to be based on qualification tests performed in accordance with Chapter 12.

4.4.2 In all cases where tack welds, in the root of the weld seam, are used to retain plates or parts in position prior to welding, they are to be removed in the process of welding the seam.

4.4.3 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

4.4.4 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

4.4.5 The outer surface of completed welds is to be at least flush with the surface of the plates joined, and any weld reinforcement is to provide a smooth transition and gradual change of section with the plate surface.

4.4.6 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, this is to be to the same standard as required for the main vessel shell construction.

4.4.7 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post-weld heat treatment.

4.4.8 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

4.5 General requirements for routine weld production tests

4.5.1 Routine weld production tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

4.5.2 Routine production test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

4.5.3 Routine production weld tests are not required for Class 3 pressure vessels unless there are doubts about the weld quality where check tests may be requested by the Surveyor.

4.5.4 Routine production test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

4.5.5 Routine production weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

4.6 Production test plate assembly requirements

4.6.1 Two test plates and one complete test assembly, of sufficient dimensions to provide all the required mechanical test specimens is to be prepared for each vessel and is to be welded as a continuation and simulation of the longitudinal weld joint.

4.6.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam. In these cases the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

4.6.3 Where the vessel size or design results in a small number of longitudinal weld seams, one test assembly may be prepared for testing provided that the welding details are the same for each seam.

4.6.4 Test plate materials are to be the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test assembly is to be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimised.

4.6.5 As far as practicable, welding is to be performed by different welders where there is a requirement for several routine tests to be welded.

4.6.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test welds prior to mechanical testing is not permitted.

4.6.7 Where the pressure vessel is required to be subjected to post-weld heat treatment, the test weld is to be heat treated, after welding, in accordance with the same requirements. This may be performed separately from the vessel.

4.7 Inspection and testing

4.7.1 The test weld is to be subjected to the same type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination is to be performed prior to removing specimens for mechanical testing, but after any post-weld heat treatment.

4.7.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as given in 4.8.

4.8 Mechanical requirements

4.8.1 The routine production test assembly is to be machined to provide the following test specimens:
(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact (*see* Table 13.4.1).
(e) Macrograph and hardness survey of full weld section.

4.8.2 One set of specimens for mechanical testing are to be removed, as shown in Figs. 13.4.1 or 13.4.2 as appropriate for the Class of approval. Impact tests are to be removed and tested where required by Table 13.4.1.

4.8.3 **Longitudinal tensile test for weld metal**. An all-weld metal longitudinal tensile test is required. For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens are to be tested in accordance with the following requirements:
(a) The diameter and gauge length of the test specimen is to be in accordance with Ch 11,2.1.1.
(b) For carbon and carbon-manganese steels the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:
A = (980-R)/21,6 but not less than 80 per cent of the minimum elongation specified for the plate

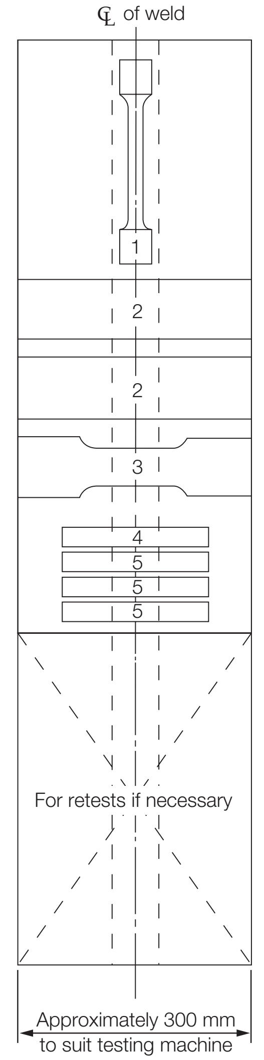
where
R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile tests.
(c) For other materials the tensile strength and percentage elongation is not to be less than that specified for the base materials welded.

4.8.4 **Transverse tensile test for joint**. Transverse tensile test specimens are to be removed and tested in accordance with the following requirements:
(a) One reduced section tensile test specimen is to be cut transversely to the weld to the dimensions shown in Ch 11,2.1.1 and the weld reinforcement is to be removed.

Table 13.4.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness t	Impact test temperature
Class 1 *see* Note	–10°C or above	All	5°C below the minimum design temperature or 20°C, whichever is the lower
All Classes	Below –10°C	$t \le 20$ mm	5°C below the minimum design temperature
		20 mm $< t \le 40$ mm	10°C below the minimum design temperature
		Over 40 mm	Subject to special consideration

NOTE
Impact testing is not required for Classes 2/1, 2/2 and 3.

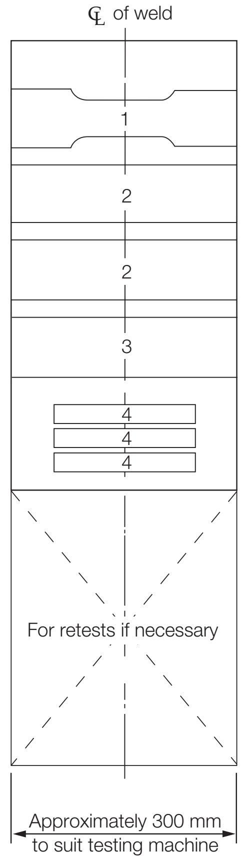


1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact.
(For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1

(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.

(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.



1. Tensile test for joints.
2. Bend test specimens.
3. Nicked bend test specimen.
4. Charpy V-notch impact test specimens (if required by Table 13.4.1).

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

4.8.5 **Transverse bend test**. The bend test specimens are to be removed and tested in accordance with the following requirements:

(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).

(b) The specimen dimensions are to be in accordance with Chapter 2.

(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The former is to have a diameter specified in Ch 12,2.7.6 depending on the material being welded.

(d) After bending through an angle of at least 180° there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen is not to be cause for rejection, unless this is associated with a weld defect.

4.8.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test assembly near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following requirements:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.
(b) The specimen is to show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.
(c) Where there is doubt in the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.
(d) For carbon, carbon manganese and low alloy steels, a Vickers hardness survey is to be performed on the macro-specimen using either a 5 kg or 10 kg load. Testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed as specified in Fig. 12.2.9 in Chapter 12. The maximum recorded hardness is to not exceed 350 Hv.

4.8.7 **Charpy V-notch impact test**. Charpy V notch impact test specimens are to be prepared and tested as required by Table 13.4.1 and in accordance with the following requirements:

(a) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2.
(b) Charpy V-notch impact specimens and are to be removed with the notch perpendicular to the plate surface.
(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations) detailed in Fig. 12.2.6 or Fig. 12.2.7 in Chapter 12, as appropriate. Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.
(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective areas of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.
(e) The average energy of a set of three specimens is not to be less than 27 J or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2.

4.8.8 **Nick break bend tests**. A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and is to be tested in accordance with and meet the requirements of the following:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.
(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces are to be examined for defects. The weld is to be sound, with no evidence of cracking or lack of fusion or penetration and be substantially free from slag inclusions and porosity.

4.9 Failure to meet requirements

4.9.1 Where any test specimen fails to meet the requirements, additional specimens may be removed and re-tested in accordance with Ch 2,1.4.

4.9.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established, and the manufacturer is to take such steps as necessary to either

(a) Remove the affected welds and have them re-welded, or
(b) Demonstrate that the affected production welds have acceptable properties.

4.10 Post-weld heat treatment

4.10.1 Fusion welded pressure vessels, where indicated in Table 13.4.2, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

4.10.2 Tubes which have been expanded into headers or drums may be seal welded without further post-weld heat treatment.

4.10.3 Steam and gas turbine cylinders and rotors are to be subjected to post-weld heat treatment irrespective of thickness.

4.10.4 Where the weld attaches parts of different thicknesses, the thickness to be used when applying the requirements for post-weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for welds to flanges, tubeplates and similar connections.

4.10.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

4.11 Basic requirements for post-weld heat treatment of fusion welded pressure vessels

4.11.1 Recommended soaking temperatures and soak durations for post-weld heat treatment are given in Table 13.4.3 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

4.11.2 Where pressure vessels are of dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

4.11.3 Where materials other than those detailed in Table 13.4.3 are used or where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases, it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Table 13.4.2 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post-weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr ½Mo	All thicknesses	All thicknesses
2¼Cr 1Mo	All thicknesses	All thicknesses
½Cr ½Mo ¼V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration	

Table 13.4.3 Post-weld soak temperatures and times

Material type	Soak temperature (°C)	Soak period
Carbon and carbon/manganese grades	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be lower than the material tempering temperature.		

4.12 Non-Destructive Examination of welds

4.12.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognised code or standard.

4.12.2 NDE is not to be applied until an interval of at least 48 hours has elapsed since the completion of welding.

4.12.3 NDE Personnel are to be qualified to an appropriate level of a nationally recognised certification scheme.

4.12.4 Qualification schemes are to include assessments of practical ability for Levels I and II individuals. These examinations are to be made on representative test pieces containing relevant defects.

4.13 Extent of NDE for Class 1 pressure vessels

4.13.1 All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles with outside diameter greater than 170 mm, are subject to 100 per cent volumetric and surface crack detection inspections.

4.13.2 For circumferential butt welds in extruded connections, tubes, headers and other tubular parts with an outside diameter of 170 mm or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

4.13.3 Full penetration tube sheet to shell welds are to be subjected to 10 per cent volumetric examination and 10 per cent surface inspection, prior to the installation of the tubes.

4.13.4 In addition to the acceptance limits stated in Tables 13.2.4 to 13.2.6, no cracks, lack of fusion, or lack of penetration is permitted.

4.13.5 When an unacceptable indication is detected, the full length of the weld is to be subjected to 100 per cent examination by the same method, testing conditions and acceptance criteria.

4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.1 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. Where further unacceptable defects are found either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated, or

(b) the whole length of the weld represented is to be re-examined using the same inspection methods.

4.14.2 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot volumetric examination. The minimum length for each check point is to be 300 mm.

4.14.3 The extent of NDE for turbine cylinders and rotors is to be agreed with the Surveyor.

4.14.4 The requirements of 4.13.3, 4.13.4 and 4.13.5 apply to Class 2/1 pressure vessels.

4.15 NDE Method

4.15.1 Volumetric examinations may be made by radiography. For welds of nominal thickness greater than or equal to 8 mm, the examinations may be by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection. The preferred method for non-magnetic materials is liquid penetrant inspection.

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

4.17 Repair to welds

4.17.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with 1.15 and are to be shown by further non-destructive examinations to have been eliminated.

4.17.2 In the case where spot radiography has revealed unacceptable defects, the requirements of 4.14.1 apply.

4.17.3 Where post-weld heat treatment is required in accordance with 4.10, weld repairs to the vessel or cylindrical shell or parts attaching to the shell are to be subjected to a subsequent heat treatment in accordance with 4.10.

4.17.4 In the event of unsuccessful weld repair of a defect, only one more repair attempt may be made of the same defect. Any subsequent repairs may require the re-repair excavation to be enlarged to remove the original repair heat affected zone.

■ *Section 5*
Specific requirements for pressure pipework

5.1 Scope

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section and the general requirements given in Section 1, unless more stringent requirements have been specified.

5.1.2 Piping systems are to be constructed in accordance with the approved plans and specifications.

5.1.3 Fabricated pipework will be accepted only if manufactured by firms that have demonstrated that they have the facilities and equipment and are competent to undertake the quality of welding required for the Class of pipework proposed.

5.2 Manufacture and workmanship

5.2.1 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel or carbon/manganese material that is not for carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm thickness.

5.2.2 Welding of pipework, including attachment welds directly to pressure retaining parts is to be performed in accordance with approved welding procedures that have been qualified in accordance with Chapter 12.

5.2.3 Where the work involves a significant number of branch connections, tests will be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

5.2.4 Where pressure pipework is assembled and butt welded insitu, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and non-destructive examination of the joints.

5.2.5 Alignment of pipe butt welds is to be in accordance with Table 13.5.1 unless more stringent requirements have been agreed. Where fusible inserts are used, the alignment is to be within 0,5 mm in all cases.

5.2.6 The number of welds is to be kept to a minimum. The minimum separation between welds, measured toe-to-toe, is to be not be less than 75 mm. Where it is not possible to achieve this, adjacent welds are to be subjected to surface crack detection NDE.

5.2.7 Welding consumables and fusible root inserts, where used, are to be suitable for the materials being joined.

Table 13.5.1 Pipe butt weld alignment tolerances

Pipe size	Maximum permitted misalignment
D < 150 mm and $t \leq$ 6 mm	1,0 mm or 25% of t, whichever is the lesser
D < 300 mm and $t \leq$ 9,5 mm	1,5 mm or 25% of t, whichever is the lesser
$D \geq$ 300 and t > 9,5 mm	2,0 mm or 25% of t, whichever is the lesser
where D = pipe internal diameter t = pipe wall thickness	

5.2.8 Acceptable methods of flange attachment are to be used, *see* Fig. 12.2.2 in Pt 5, Ch 12 of the Rules for Ships. Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

5.2.9 Where socket welded fittings are employed, the diametrical clearance between the outside diameter of the pipe and the base of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the internal step at the bottom of the socket.

5.2.10 For welding of carbon, carbon/manganese and low alloy steels, the preheat to be applied will be dependent on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 13.5.2, unless welding procedure testing indicates that a higher level is required.

5.2.11 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.12 All welds in high pressure, high temperature pipelines are to have a smooth surface finish and even contour; and where necessary, made smooth by grinding.

5.2.13 Check tests of the quality of the welding are to be carried out periodically.

5.3 Heat treatment after bending of pipes

5.3.1 After forming or bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr 1/2Mo, 2 1/4Cr 1Mo and 1/2Cr 1/2Mo 1/4V, a subsequent tempering heat treatment in accordance with the temperatures and times specified in Table 13.5.3 is required, irrespective of material thickness.

5.3.3 When hot forming is performed outside the normalising temperature range, a subsequent heat treatment in accordance with Table 13.5.3 is required.

5.3.4 After cold forming to a radius (measured at the centreline of the pipe) of less than four times the outside diameter, heat treatment in accordance with Table 13.5.3 is required.

5.3.5 Heat treatment should be carried out in accordance with 1.16.

Table 13.5.2 Welding preheat levels for pipework

Material Grade	Thickness, t (mm) *see* Note 4	Minimum preheat temperature (°C) *See* Note 1	
		Non-low H_2	Low H_2 *see* Note 2
Carbon and carbon/manganese grades: 320 and 360	$t \leq 15$ $t \geq 15$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \leq 15$ $t \geq 15$	75 150	20 100
1Cr ½Mo	$t < 13$ $t \geq 13$	*See* Note 3	100 150
2¼Cr 1Mo	$t < 13$ $t \geq 13$	*See* Note 3	150 200
½Cr ½Mo ¼V	$t < 13$ $t \geq 13$	*See* Note 3	150 200

NOTES
1. Where the ambient temperature is 0°C or below, pre-warming of the weld joint is required in all cases.
2. Low hydrogen process or consumables are those that have been tested and have achieved a grading of H15 or better (*see* Chapter 11).
3. Low hydrogen welding process is required for these materials.
4. t = the thickness of the thinner member for butt welds, and the thicker member for fillet and branch welds.

Table 13.5.3 Heat treatment after bending of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalise at 880 to 940°C
1Cr ½Mo	Normalise at 900 to 940°C, followed by tempering at 640 to 720°C
2¼Cr 1Mo	Normalise at 900 to 960°C, followed by tempering at 650 to 780°C
½Cr ½Mo ¼V	Normalise at 930 to 980°C, followed by tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

5.3.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

5.4.1 Post-weld heat treatment is to be carried out in accordance with the general requirements specified in 1.16 and 4.10.

5.4.2 The thickness limits, the recommended soaking temperatures and periods, for application of post-weld heat treatment are given in Table 13.5.4.

5.4.3 Where the use of oxy-acetylene welding is proposed, due consideration is to be given to the need for normalising and tempering after such welding.

5.5 Non-destructive examination

5.5.1 Non-destructive examination of pipe welds is to be carried out in accordance with the general requirements of 1.11 and the following.

5.5.2 Butt welds in Class 1 pipes with an outside diameter greater or equal to 75 mm are to be subject to 100 per cent volumetric and visual inspections. Consideration is to be given to the extent and method of testing applied to butt welds in Class 1 pipes with an outside diameter less than 75 mm.

5.5.3 Butt welds in Class II pipes are to be subjected to at least 10 per cent random volumetric inspections when the outside diameter is greater than 100 mm.

5.5.4 NDE for Class II pipes with a diameter less than 100 mm is to be at the discretion of the Surveyor.

5.5.5 Non-destructive examination procedures, methods and the evaluation of reports are to be in accordance with 4.15 and 4.16.

5.5.6 Fillet welds on flange pipe connections of Class I pipes are to be examined by surface crack detection methods.

5.6 Repairs to pipe welds

5.6.1 Where non-destructive examinations reveal unacceptable defects in a weld, the defects are to be removed and repaired in accordance with 1.15. Completed repairs are to be shown by further non-destructive examination to have eliminated the defects.

5.6.2 For pipes with diameter less than 88 mm and where unacceptable defects have been found during non-destructive examination, consideration is to be given to cutting the weld out completely, re-making the weld preparation and re-welding as a new joint (because of the difficulty of making small repairs).

Table 13.5.4 Post-weld heat treatment requirements for pipework

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature (°C) *see* Note 2	Soak period
Carbon and carbon/manganese grades: 320, 360, 410, 460, 490	Over 30 mm	580–620°C	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	Over 8 mm	620–660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	All	650–690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	All, *see* Note 1	670–720°C	1 hour per 25 mm of thickness, minimum of 1 hour

NOTES
1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100 mm provided welding procedure tests have demonstrated acceptable properties in the as welded condition.
2. For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.

5.6.3 Where repeated weld repairs have to be made to a weld, only two such attempts are to be permitted, thereafter the weld is to be cut apart and removed, and re-welded as a new joint.

5.6.4 Where pipework requires post-weld heat treatment weld, repairs to the pressure retaining parts are to be subjected to a subsequent heat treatment. Similarly, where welding is conducted after pressure testing, a further pressure test is to be required unless specific exemption has been agreed.

■ *Section 6*
Repair of existing ships by welding

6.1 Scope

6.1.1 This Section specifies requirements for repairs made by welding after introduction into service. This Section includes defects to hull structures, machinery, equipment and components. It also includes replacement of structure due to damage or corrosion. These requirements are in addition to those specified in the preceding Sections of this Chapter.

6.1.2 These requirements apply unless the original builder or manufacturer has specified alternative requirements.

6.2 Materials used for repairs

6.2.1 Permanent materials used in the repair are to be in accordance with 1.3.

6.2.2 Prior to commencing any welding, the material grades present in the original structure in way of the repair are to be determined. Where the materials cannot be identified from the ship records, test samples may be removed for chemical analysis and mechanical testing in order to determine the material grades.

6.2.3 Temporary materials that are to be welded to the main structure to assist in executing the repairs, but removed on completion, are to be of weldable quality.

6.3 Workmanship

6.3.1 A repair method is to be established by the shipyard or repair yard and is to be agreed by the Surveyor prior to commencing any repair work.

6.3.2 The removal of crack-like defects is to be confirmed by visual examination and surface crack detection NDE. This may be augmented by ultrasonic examination where several defects are reported at different depths at the same location.

6.3.3 The weld joint or groove shape used for the repair is to have a profile suitable for welding.

6.3.4 The weld area is to be carefully cleaned, in particular, where the material surface has been painted or has been subjected to an oily or greasy environment.

6.4 Non-destructive examination

6.4.1 On completion of welding and any post-weld heat treatment, repair welds are to be subjected to the type and extent of NDE and assessed in accordance with the acceptance criteria specified for the original construction.

6.4.2 Where the original construction specification did not specify NDE, the completed welds are to be, as a minimum, subject to visual examination. Consideration of other NDE techniques is to take due cognisance of the location or the repair within the vessel.

6.4.3 Where spot NDE is applied and defects are found, the extent of NDE is to be increased to include an equal amount of weld length. Where this reveals unacceptable defects, either the whole weld will be rejected or the extent of inspection increased to 100 per cent examination.

6.4.4 The acceptance criteria to be applied are to generally be in accordance with the original build specification. Where conflict of requirements exist, the NDE acceptance limits for welding procedure tests specified in Ch 12,2.5.5 may be used as a minimum requirement.

6.5 Repairs to welds defects

6.5.1 Where NDE reveals unacceptable defects, these are to be repaired in accordance with 1.15.

■ *Section 7*
Austenitic and duplex stainless steel – Specific requirements

7.1 Scope

7.1.1 This Section specifies requirements for the fabrication and welding of austenitic and duplex stainless steels, and is in addition to those detailed above.

7.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

7.1.3 All tools and equipment used are to be suitable for use on stainless steel materials. The use of tools or equipment made of carbon steel materials is to be avoided. It is permissible to use carbon steel tools provided that the surfaces that come into contact with the austenitic and duplex stainless materials are protected with an austenitic or nickel base alloy.

7.2 Design

7.2.1 Care is to be exercised in the weld design to prevent crevice corrosion from occurring, particularly where austenitic materials are used. In this respect fillet welds and partial penetration welds are to be continuous and welded on both sides of the joint.

7.3 Forming and bending

7.3.1 Materials that are cold formed, such that the total strain exceeds 15 per cent (i.e., where the formed diameter to thickness ratio is less than 6:1) are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturers recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

7.3.2 Materials may be hot formed provided that a subsequent softening heat treatment is carried out. The forming process and the subsequent heat treatment are to be in accordance with the material manufacturer's recommendations.

7.4 Fabrication and welding

7.4.1 Welding may be performed using shielded manual arc welding (SMAW), gas tungsten arc welding (GTAW), MIG/MAG welding (GMAW), flux cored arc welding (FCAW), plasma arc welding (PAW) and submerged arc welding (SAW). The use of other welding processes will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

7.4.2 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

7.4.3 For full penetration welds, a backing or shielding gas is to be provided to prevent oxidation of the root weld. The backing gas is to be maintained until completion of, at least, the root and first fill layer. The backing gas may be omitted where the weld is back gouged or ground to remove the root weld.

7.4.4 Shielding and backing gases are to be an inert type of high purity and oxygen free.

7.4.5 For welding of Duplex stainless, the use of backing gases that contain up to 2 per cent nitrogen is permitted.

7.4.6 Welding of duplex stainless steels without filler metal is generally not permitted.

7.4.7 Degreasing agents, acid solutions, washing water etc. used for cleaning and any marking crayons and paints used are to be free of chlorides.

7.5 Repairs

7.5.1 Correction of distortion by the application of heat is not permitted.

■ *Section 8* Specific requirements for welded aluminium

8.1 Scope

8.1.1 This Section specifies requirements for the fabrication and welding of aluminium alloys, and is in addition to those detailed in this Chapter.

8.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels, stainless steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

8.1.3 All tools and equipment used are to be suitable for use on aluminium alloy materials. The use of tools made of carbon steel materials is to be avoided where possible.

8.2 Forming and bending

8.2.1 Aluminium alloys are to be subject to cold forming and cold bending only.

8.3 Fabrication and welding

8.3.1 Welding may be performed using gas tungsten arc welding (GTAW) or metal inert gas welding (GMAW), MIG/MAG welding (GMAW), or variants thereof. The use of other welding processes such as friction stir welding (FSW) will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

8.3.2 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 13.8.1.

8.3.3 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

8.3.4 Correction of distortion by the application of heat is not permitted.

Table 13.8.1 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm^2		Ultimate tensile strength, N/mm^2	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (see Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (see Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. See also Table 8.1.3 or Table 8.1.4 in Chapter 8.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5.
4. Where detail structural analysis is carried out, 'unwelded' stress values may be used away from heat affected zones and weld lines, *see also* Pt 3, Ch 2, 1.1.3 of the Rules for Ships.
5. For thickness less than 12,5 mm, the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

8.4 Non-destructive examination

8.4.1 The requirements of Ch 13,1.11 and Ch 13,2.12 apply; however, acceptance criteria applicable to aluminium are to be in accordance with Table 13.8.2 and Table 13.8.3.

8.4.2 Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

Table 13.8.2 Acceptance criteria for surface imperfections of aluminium

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0,3s$ or $0,3a$ or 1,5 mm (whichever is the lesser)
Linear porosity (*see* Note 1)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	≤ 1% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	$h \leq 0,1t$ or 0,5 mm (whichever is the lesser)
Intermittent undercut	5012	$h \leq 0,1t$ or 1,0 mm (whichever is the lesser)
Excess weld metal (*see* Note 3)	502	$h \leq 1,5$ mm + $0,15b$ or 8 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 3)	515	$h \leq 0,1t$ or 1 mm (whichever is the lesser)
Linear misalignment (*see* Notes 4 and 5)	507	$h \leq 0,1t$ or 1,0 mm (whichever is the lesser)
Angular misalignment	508	(*see* Note 6)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. For these acceptance criteria, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. To be in accordance with EN ISO 10042.
3. A smooth transition is required.
4. Linear misalignment is to be a maximum of 0,5 mm in highly stressed areas. For other areas, the linear misalignment is to be a maximum of 1,0 mm locally, where the sum of the length of imperfection is not more than 10% of the weld length.
5. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide.
6. Angular misalignment shall be mutually agreed between the designer and the fabricator.

Table 13.8.3 Acceptance criteria for internal imperfections of aluminium

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria (*see* Note 1)
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 5 mm (whichever is the lesser)
Linear porosity	2014	Assess as lack of fusion
Uniformly distributed porosity (*see* Note 1)	2012	$0{,}5 < t < 3$ mm ≤ 2% of area $3 < t < 12$ mm ≤ 4% of area $12 < t < 30$ mm ≤ 6% of area $t > 30$ mm ≤ 8% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 20$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0{,}5s$ or $0{,}5a$ or 5 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0{,}3s$ or $0{,}3a$ or 4 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}3t$ or $0{,}3a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.
2. If several oxide inclusions l_1, l_2, l_3, ... exist in one cross-section, then they are summed: $l = l_1 + l_2 + l_3 + ... + l_n$.

■ *Section 9* Friction stir welding requirements for aluminium alloys

9.1 Scope

9.1.1 The requirements of this Section apply to the application of FSW during construction.

9.1.2 Prior to welding, the friction stir welding equipment is to have been demonstrated as being suitable for use.

9.1.3 Qualified welding procedures that have been approved by LR are required. Procedures to ISO 25239-4 that are endorsed by another Classification Society may be accepted if they are to the satisfaction of the attending Surveyor.

9.1.4 Welding operators are to be qualified to ISO 35239-3 standard. Where qualifications have been certified by another Classification Society, acceptance of the qualifications will be subject to document review and demonstration of knowledge of the FSW process and function of the FSW installation.

9.2 Production quality control

9.2.1 The general requirements for quality control are specified in ISO 35239-5.

9.2.2 Unless otherwise specified in relevant parts of the Rules, the following production tests will be required.

9.2.3 A production test is required when there is a change in procedure, a change in tooling, after equipment repairs or modifications, after deviation from optimum parameters are detected, when defects are identified by non-destructive testing, after continuous welding of every 100 m length during a single shift and with a maximum interval between procedure tests of 8 hours. For butt welds the production tests are to consist of 100 per cent visual examination, two face bend tests, two root bend tests and one macro section. For thicknesses exceeding 12 mm, sets of face and bend tests may be replaced by side bend tests. For test assembly, *see* Fig. 13.9.1. The production tests for other joint geometry are to be agreed between the Surveyor and the fabricator.

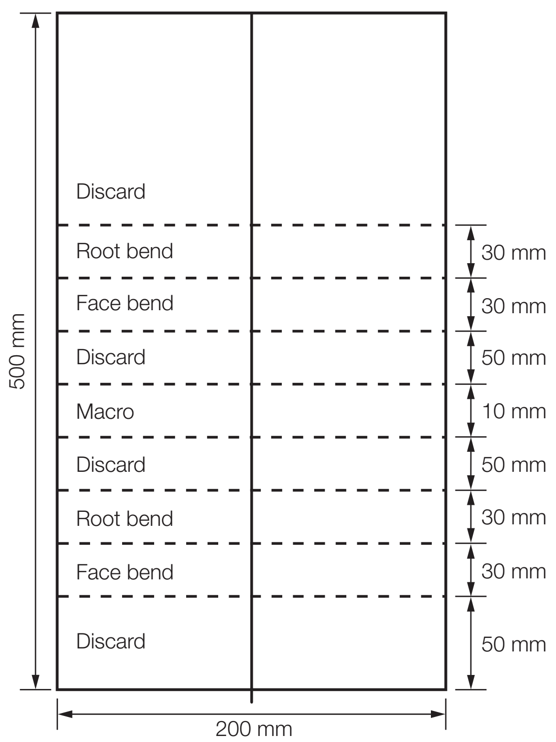


Fig. 13.9.1 Production test assembly for Friction Stir Welds

9.2.4 As an automated process, all essential variables are to be recorded by the FSW system. The welding operator is responsible for ensuring that the system continues to produce welds that are in compliance with the qualified procedure. Surveyors are to be informed when the system exceeds the operating parameters. Surveyors are periodically to review the welding records.

9.2.5 Production welds are to be subject to 100 per cent visual examination by the fabricator and be subject to random checking by the Surveyor.

9.2.6 Surface and volumetric NDE testing is to be conducted on production welds at a frequency of two per welded panel or one every 100 m of weld, whichever is the greater.

9.2.7 Assessment of imperfections is to be in accordance with ISO 35239-5 Annex A and the requirements of Table 13.8.3.

9.3 Repair

9.3.1 All defective welds are to be reported to the Surveyor.

9.3.2 The manufacturer is to have an approved procedure for the repair of defective welds.

9.3.3 Weld repairs are to be conducted by qualified welders or welding operators in accordance with qualified weld procedures. Welding procedures and welders/operators are to be qualified in accordance with the requirements of Chapter 12 as appropriate to the welding process used for the weld repair.

9.3.4 All repairs are to be subject to 100 per cent visual, surface and volumetric NDE.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 Provision is made in this Chapter for the manufacture and testing of plastics pipes, together with approval requirements for base materials used in the construction or repair of composite vessels, other marine structures, piping and any associated machinery components and fittings which are to be certified or are intended for classification.

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3 of this Chapter; and LR's *Materials and Qualification Procedures for Ships (MQPS) Book K*, *see* Ch 1,2.2.2, which, in addition to the test programme, also details the procedures for application for approval of manufacturers and products and details of the information to be supplied by the manufacturer.

1.1.3 For base materials, the manufacturer's works do not require approval by Lloyd's Register (hereinafter referred to as 'LR'), however the Quality Control procedures must be acceptable in accordance with the appropriate Section of this Chapter.

1.1.4 Where a requirement exists for the material to be approved, the test requirements and information to be submitted for approval of polymers, resins, reinforcements and associated materials are defined in Sections 2 and 3.

1.1.5 Specific material requirements relating to the design and manufacture of plastics pipes and fittings are indicated in Section 4, with the material requirements for hull structures contained in Section 5.

1.1.6 For Builders constructing composite vessels, Section 5 provides the minimum material control requirements for acceptance of the works by LR.

1.1.7 For the purposes of these Rules a 'plastics material' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives.

1.1.8 Materials not listed in 2.1.1 may be considered for approval on a case-by-case basis. The approved test results will be listed on the issued certificate. Subject to satisfactory service experience and validation of approval, the material may be entered in 2.1.1 of the Rules.

1.2 Information on material quality and application

1.2.1 Where plastics products are to be classed or certified, the manufacturer is to provide the material producer with such information as is essential to ensure that the base materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

1.3 Manufacture

1.3.1 Plastics products are to be made at works which have been approved (or accepted) for the type of product being supplied using base materials that have been approved.

1.3.2 Base materials are to be approved in accordance with the requirements of Sections 2 and 3.

1.3.3 In order that a works can be approved (or accepted), the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A specified programme of tests is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR. When a manufacturer has more than one works, the approval (or acceptance) is only valid for the individual works which carried out the test programme.

1.3.4 In order to maintain approval, the manufacturer is required to confirm in writing that there have been no changes in the formulation or production process for the material in question and that the site of manufacture remains unchanged.

1.4 Survey procedure

1.4.1 The Surveyors are to be allowed access to all relevant parts of the works and are to be provided with the necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Facilities are also to be provided for the selection of test material, the witnessing of specified tests and the examination of materials, as required by the Rules.

1.4.2 Prior to the provision of test material for acceptance, manufacturers are to provide the Surveyors with details of the order, specification and any special conditions additional to the Rule requirements.

1.4.3 Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and any Rule requirements and are to be to the satisfaction of the Surveyors.

1.4.4 These specified tests and examinations are to be carried out prior to the despatch of finished products from the manufacturer's works.

1.4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, notwithstanding any previous certification.

1.5 Alternative survey procedure

1.5.1 Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

1.5.2 In order to be considered for approval, manufacturers are to comply with the requirements of Ch 1,2.

1.6 Post-cure heating

1.6.1 Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

1.7 Test material

1.7.1 Sufficient material is to be provided for the preparation of the test specimens detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

1.7.2 Where test materials, (either base materials or product sample materials) are selected by the Surveyor or a person nominated by LR, these are to be suitably identified by markings which are to be maintained during the preparation of the test specimens.

1.7.3 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.

1.7.4 During production, check test samples are to be provided as requested by the Surveyor.

1.7.5 Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.

1.7.6 The dimensions, number and orientation of test specimens are to be in accordance with the requirements of a National or International Standard acceptable to LR.

1.8 Re-test procedure

1.8.1 Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.

1.8.2 Where an individual test result in a group, (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

1.9 Visual and non-destructive examination

1.9.1 Prior to the final acceptance, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in Sections 3, 4 and 5 of this Chapter.

1.9.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws or suspicious surface marks, it is to be the responsibility of the manufacturer to prove the quality of the material by any suitable method.

1.10 Rectification of defective material

1.10.1 Small surface blemishes may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from structural defects and the rectification has been completed to the satisfaction of the Surveyor.

1.10.2 Repair procedures for larger defects are to be agreed with LR prior to implementation.

1.11 Identification of products and base materials

1.11.1 The manufacturer of approved materials is to identify each batch with a unique number.

1.11.2 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

1.11.3 When any item has been identified by the personal mark of a Surveyor, or deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

1.11.4 Before any pipe or fitting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements as given in Section 4.

1.11.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

1.12 Certification

1.12.1 Certification of the finished product is to be in accordance with the requirements of the appropriate Sections.

■ *Section 2* Tests on polymers, resins, reinforcements and associated materials

2.1 Scope

2.1.1 This Section gives the tests and data required by LR for materials approval and/or inspection purposes on the following:

(a) Thermoplastic polymers.
(b) Thermosetting resins.
(c) Reinforcements.
(d) Reinforced thermoplastic polymers.
(e) Reinforced thermosetting resins.
(f) Core materials.
  (i) End-grain balsa.
  (ii) Rigid foams.
  (iii) Synthetic felt type materials.
(g) Machinery chocking compounds.
(h) Rudder and pintle bearings.
(j) Stern tube bearings.
(k) Plywoods.
(l) Adhesive and sealant materials.
(m) Repair compounds.

2.2 Thermoplastic polymers

2.2.1 The following data is to be provided by the manufacturer for each thermoplastic polymer:

(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Bulk density.
(e) Filler content, where applicable.
(f) Pigment content, where applicable.
(g) Colour.

2.2.2 Samples for testing are to be prepared by moulding or extrusion under the polymer manufacturer's recommended conditions.

2.2.3 The following tests are to be carried out on these samples:

(a) Tensile stress at yield and break.
(b) Modulus of elasticity in tension.
(c) Tensile strain at yield and break.
(d) Compressive stress at yield and break.
(e) Compressive modulus.
(f) Temperature of deflection under load.
(g) Determination of water absorption.

2.3 Thermosetting resins

2.3.1 The data listed in Table 14.2.1 is to be provided by the manufacturer for each thermosetting resin.

Table 14.2.1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester (*see* Note 3 for vinylester)	Epoxide	Phenolic
Specific gravity of liquid resin	required	required	required
Viscosity	required	required	required
Gel time	required	required	not applicable
Appearance	required	required	required
Mineral content (*see* Note 1)	required	required	not applicable (*see* Note 2)
Volatile content	required	not applicable	not applicable
Acid value	required	not applicable	not applicable
Epoxide content	not applicable	required	not applicable
Free phenol	not applicable	not applicable	required
Free formaldehyde	not applicable	not applicable	required

NOTES
1. This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
2. If the resin is pre-filled, the mineral content is required.
3. Vinylesters are to be treated as equivalent to polyesters.

2.3.2 Cast samples are to be prepared in accordance with the manufacturer's recommendations and are to be cured and post-cured in a manner consistent with the intended use. The curing system used and the ratio of curing agent (or catalyst) to resin are to be recorded. Where post-cure conditions equivalent to ambient-cure conditions apply, *see* 3.2.2 and 3.2.3.

2.3.3 The following are to be determined using these samples:
(a) Tensile strength (stress at maximum load) and stress at break.
(b) Tensile strain at maximum load.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Temperature of deflection under load.
(e) Barcol hardness.
(f) Determination of water absorption.
(g) Volume shrinkage after cure.
(h) Specific gravity of cast resin.

2.3.4 In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.

2.3.5 Where resins which have been modified by the addition of waxes or polymers, for example ‘low styrene emission or air inhibited’ materials, it is to be confirmed that the use of such resins will not result in poor interlaminar adhesion when interruptions to the laminating process occur. The test procedure is to be as follows:
(a) A conventional room temperature curing catalyst/accelerator system is to be used with the resin for laminate preparation.
(b) A laminate of 25 to 35 per cent glass content in mass is to be prepared using two plies of 450 g/m^2 chopped strand mat. The laminate is to be prepared at ambient temperature (18° to 21°C). The laminate is to be allowed to stand for a minimum of four days but no longer than 6 days at ambient temperature.
(c) A further two plies of 450 g/m^2 chopped strand mat are to be laminated onto the exposed surface and cured at ambient temperature for 24 hours. The finished laminate is then to be post-cured at 40°C for 16 hours. The finished laminate is to have a glass content of 25 to 35 per cent.
(d) After cooling, the apparent interlaminar shear strength of the laminate is to be determined in accordance with ISO 14130; the minimum value is given in Table 14.5.5. Before testing the samples shall be conditioned at 23°C and relative humidity of 50 per cent for a period of 88 hours before testing.
(e) If the tests are undertaken at the resin manufacturer’s own laboratory, the individual test values are to be reported and the broken test specimens retained for examination by LR.

Alternative test procedures will be considered with prior agreement.

2.4 Reinforcements

2.4.1 The following data is to be provided, where applicable, for each type of reinforcement:
(a) Reinforcement type.
(b) Fibre type for each direction.
(c) Fibre tex value.
(d) Fibre finish and/or treatment.
(e) Yarn count in each direction.
(f) Width of manufactured reinforcement.
(g) Weight per unit area of manufactured reinforcement.
(h) Weight per linear metre of manufactured reinforcement.
(j) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
(k) Constructional stitching – details of yarn, specific gravity, type, frequency and direction.
(l) Weave type.
(m) Binder type and content.
(n) Density of the fibre material.

2.4.2 Tests of the mechanical properties are to be made on laminate samples containing the reinforcement and prepared as follows:
(a) an approved resin of suitable type is to be used;
(b) a minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick;
(c) the weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used;
(d) for glass reinforcements, the glass/resin ratios, by weight, as shown in Table 14.2.2 are to be used;
(e) for reinforcement type other than glass, a fibre volume fraction, as shown in Table 14.2.3, is to be used.

Table 14.2.2 Glass fraction by weight for different reinforcement types

Reinforcement type	Glass fraction nominal values
Unidirectional	0,60
Chopped strand mat	0,30
Woven roving	0,50
Woven cloth	0,50
Composite roving (*see* Note)	0,45
Gun rovings	0,33
±45° stitched parallel plied roving	0,50
Triaxial parallel plied roving	0,50
Quadriaxial parallel plied roving	0,50
NOTE Continuous fibre reinforcement with attached chopped strand mat.	

2.4.3 Rovings intended for filament winding are to be tested as unidirectional rovings.

2.4.4 The following tests as defined in Section 3 are to be made on the samples:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Apparent interlaminar shear.

Table 14.2.3 Content by volume for different reinforcement types

Reinforcement type	Content by volume nominal values
Unidirectional	0,41
Chopped strand mat	0,17
Woven roving	0,32
Woven cloth	0,32
Composite roving (*see* Note)	0,28
Gun rovings	0,19
±45° stitched parallel plied roving	0,32
Triaxial parallel plied roving	0,32
Quadriaxial parallel plied roving	0,32

NOTE
The volume content may be converted to weight fractions by use of the formula:

$W_F = V_F D_F/(D_F V_F + D_R V_R)$

where

W_F = fibre fraction by weight
D_F = density of fibre
D_R = density of cured resin
V_F = fibre fraction by volume
V_R = resin fraction by volume

(j) Fibre content.
(k) Determination of water absorption.

2.4.5 The laminate is to be tested in air in the directions indicated by Table 14.2.4.

Table 14.2.4 Fibre orientations in reinforced test specimens

Type of reinforcement	Test orientations
Unidirectional	0°
Chopped strand mat Gun roving	any direction
Woven roving Woven cloth Composite roving	0° and 90°
± 45° parallel plied roving Triaxial plied roving Quadriaxial plied roving	0°, 45°, 90° and –45°

2.4.6 Additionally, tests in 2.4.4(c) and (f) are to be repeated, in one direction only, after immersion in fresh water at 35°C for 28 days with the exception of 2.4.4(k).

2.5 Reinforced thermoplastic polymers

2.5.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with 2.2.1 to 2.2.3.

2.5.2 A laminate is to be prepared using the polymer and an approved reinforcement in accordance with a manufacturing specification. The laminate is to be tested in accordance with the appropriate requirements of 2.4.4. Testing may be confined to one direction only.

2.6 Reinforced thermosetting resins

2.6.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with 2.3.1 to 2.3.4.

2.6.2 No further tests are required for gel coat resins.

2.6.3 For laminating resins, a laminate is to be prepared using the resin and an approved reinforcement as follows:
(a) For polyester resins, chopped strand mat.
(b) For epoxide resins, a balanced woven roving.
(c) For phenolic resins, a balanced woven material.

2.6.4 The laminate is to be tested in accordance with procedures outlined in MQPS Book K procedure 14-1 and 2.4.4 in one fibre direction only.

2.7 Core materials

2.7.1 **General requirements**. The following data is to be provided for each type of core material:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

2.7.2 Manufacturers are required to provide a full application procedure for use of the product.

2.8 Specific requirements for end-grain balsa

2.8.1 The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenisation, sterilisation and kiln drying to an average moisture content of no more than 12 per cent.

2.8.2 The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain:
(a) Compressive strength (stress at maximum load).
(b) Compressive modulus of elasticity.
(c) Tensile strength (stress at maximum load).
The density of the virgin material is also to be tested.

2.8.3 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.

2.8.4 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9 Specific requirements for rigid foams (PVC, Polyurethane and other types)

2.9.1 The foam is to be of the closed cell type and compatible with the proposed resin system (e.g., polyester, epoxide, etc.).

2.9.2 Foams are to be of uniform cell structure.

2.9.3 Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

2.9.4 The following test data is to be submitted for each type of foam:

(a) Density.
(b) Tensile strength (stress at maximum load).
(c) Tensile modulus of elasticity.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus of elasticity.

2.9.5 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9.6 Additionally, the compressive properties (*see* 2.9.4(d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70°C, whichever is the greater.

2.10 Synthetic felt type materials with or without microspheres

2.10.1 For materials of this type, the following data is required in addition to the requirements of 2.7.1:

(a) Fibre type.
(b) Width.
(c) Width of finished material.
(d) Weight per unit area of the manufactured material.
(e) Weight per linear metre of the manufactured material.
(f) Compatibility.
(g) Details of the method of combining.

2.10.2 A laminate of the material is to be prepared using a suitable approved resin under conditions recommended by the manufacturer.

2.10.3 The following properties are to be determined:

(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Modulus of elasticity in tension or secant modulus at 0,25 per cent and 0,5 per cent strain.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Fibre content.
(j) Water absorption.

2.10.4 In the case of anisotropic materials (e.g., where combined with other reinforcements) the tests listed in 2.10.3 are to be conducted in the 0°, 90° directions and in any other reinforcement direction.

2.10.5 Additionally, the tests listed in 2.10.3 are to be repeated after immersion in fresh water at 35°C for 28 days. For anisotropic materials, the requirement is for this test to be carried out in one direction only.

2.10.6 The shear properties (of the resin filled system) are to be determined according to 3.8.1.

2.11 Machinery chocking compounds (resin chocks)

2.11.1 Thermosetting materials for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by LR before use.

2.11.2 Approval will be considered by LR for use under the following service conditions:

- Loading of 3,5 N/mm^2 (max) for a temperature not exceeding 60°C.
- Loading of 2,5 N/mm^2 (max) for a temperature not exceeding 80°C.
- Other loading conditions.

2.11.3 The exotherm temperature, defined as the maximum temperature achieved by the reacting resin under conditions equivalent to those of intended use, is to be determined according to a procedure approved by LR.

2.11.4 The following properties are to be determined on chock material cured at the measured exotherm temperature:

(a) The impact resistance (Izod).
(b) Hardness.
(c) Compressive strength (stress at maximum load) and modulus of elasticity.
(d) Water absorption.
(e) Oil absorption.
(f) Heat deflection temperature.
(g) Compressive creep is to be measured according to 3.9.4.
(h) Curing linear shrinkage.
(j) Flammability.

2.11.5 The chocking compound approval is contingent on the material achieving the minimum exotherm value as specified when used on an installation under practical conditions.

2.11.6 Where the resin chock is to be used for installation of sterntubes and sternbushes in addition to the requirements of 2.11.4, the tensile strength and modulus of elasticity in tension are to be measured.

2.11.7 The manufacturer's installation procedure is required to be documented and is to be to the satisfaction of LR.

2.12 Rudder and pintle bearings

2.12.1 Materials used for rudder and pintle bearings are to be approved by LR before use.

2.12.2 Initial approval is to be based on a review of the following physical properties of the material:
(a) Compressive strength (stress at maximum load) and modulus of elasticity.
(b) Tensile strength (stress at maximum load) and modulus of elasticity.
(c) Shear strength (stress at maximum load).
(d) Impact strength.
(e) Swelling in oil and in water.
(f) Hardness.

2.12.3 Additionally, friction data is to be provided under both wet and dry conditions.

2.12.4 Furthermore, the installation instructions (especially recommended clearances) are to be reviewed by LR prior to provisional approval being given.

2.12.5 If the above data is satisfactory, the material will be provisionally approved until sufficient service experience has been gained.

2.13 Sterntube bearings

2.13.1 Materials used for sterntube bearings are to be approved by LR before use.

2.13.2 Approval is to be based on a review of the physical properties as given by 2.12.2.

2.13.3 Friction data is to be provided under the lubrication system(s) proposed for the material(s).

2.14 Plywoods

2.14.1 All plywoods are to be approved to BS 1088 or equivalent National or International Standard in accordance with LR's Type Approval Procedure.

2.14.2 For structural applications in the marine environment, a minimum timber rating of moderate durability according to BS 1088-1 and BS 1088-2 is required.

2.14.3 Enhancement of durability by use of preservatives is permitted, subject to each veneer layer being treated with a recognised preservative.

2.14.4 Where Okoume, as specified by BS 1088 is involved, (i.e. non-durable timber classification) this may only be used for marine structures subject to the specific application being acceptable to LR.

2.15 Adhesive and sealant materials

2.15.1 Materials of these types are to be accepted by LR before use.

2.15.2 The requirements for acceptance are dependent on the nature of the application.

2.15.3 In the first instance, the manufacturer is to submit full details of the product, procedure for method of use (including surface preparation) and the intended application. After review of these details, LR will provide a specific test schedule for confirmation of the material's properties.

2.15.4 Any acceptance granted will be limited to specific applications and will be contingent on the instructions for use being adhered to.

2.16 Repair compounds

2.16.1 Materials used for repairs are to be accepted by LR before use.

2.16.2 For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.

2.16.3 Dependent on the proposed uses, LR may require testing in accordance with a specified test programme.

2.16.4 Materials will not be accepted for the following uses unless specific evidence of their suitability is provided:
(a) Any component in rubbing contact.
(b) Any component subject to dynamic cyclic loading.
(c) Any pressure part in contact with gas or vapour.
(d) Any pressure part in contact with liquid above 3,5 bar.
(e) Any component where operating temperature exceeds 90°C.

All uses of materials of these types are subject to the discretion of the Surveyor.

■ *Section 3* Testing procedures

3.1 General

3.1.1 This Section gives details of the test methods to be used for base materials and on finished plastics products such as fibre reinforced plastics (FRP) piping and any testing required in the construction of composite vessels.

3.1.2 In general, testing is to be carried out by a competent independent test house which, at the discretion of LR, may or may not require witnessing by the Surveyor.

3.1.3 Alternatively, testing may be carried out by the manufacturer subject to these tests being witnessed by the Surveyor.

3.1.4 All testing is to be carried out by competent personnel.

3.1.5 Unless specified otherwise, testing is to be carried out in accordance with a recognised ISO Standard, where one exists, and all test programmes are to have written procedures.

3.1.6 Alternatively, testing may be carried out in accordance with a National Standard provided that it conforms closely to an appropriate ISO standard and subject to prior agreement with the Surveyor.

3.1.7 Mechanical properties are to be established using suitable testing machines of approved types. The machines and other test equipment are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. Calibration is to be undertaken by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ±one per cent.

3.2 Preparation of test samples

3.2.1 Thermoplastic samples are to be prepared in accordance with the manufacturer's recommendations for moulding. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality plan, but where this is impractical, separate test samples are to be prepared in a manner identical with that of the product.

3.2.2 Samples of thermosetting resins are to be prepared using the curing system recommended by the manufacturer and identical with that used for the finished product.

3.2.3 The post curing conditions for samples of thermosetting resins are to be as recommended by the manufacturer and identical with those used for the finished product. Where the samples are made for the general approval of a resin, the post curing conditions are to be those in which the resin is intended to be used.

3.2.4 Where curing of the product is intended to take place at room temperature, the sample is to be allowed to cure at room temperature (18 to 21°C) for 24 hours followed by a post-cure at 40°C for 16 hours.

3.2.5 Where a reinforcement is to be used, the ratio of reinforcement to resin or polymer is to be nominally the same as that of the finished product or in accordance with Table 14.2.2 or 14.2.3.

3.2.6 Where laminates are prepared specifically for approval test purposes, the reinforcement is to be laid parallel plied.

3.3 Preparation of test specimens

3.3.1 The test specimen is to be prepared in accordance with the appropriate ISO standard and the requirements of this Section.

3.3.2 Precautions are to be taken during machining to ensure that the temperature rise in the specimen is kept to a minimum.

3.4 Testing

3.4.1 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

3.4.2 The rate of strain is to be in accordance with the appropriate ISO standard.

3.4.3 The number of test specimens from each sample to be tested is to be in accordance with the ISO standard. For mechanical testing this is five.

3.5 Discarding of test specimens

3.5.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

3.5.2 In addition, if the deviation of one result in a group of five exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested, *see* 1.8.1 and 1.8.2.

3.6 Reporting of results

3.6.1 All load/displacement graphs and tabulated results are to be reported, including mean values and the calculated standard deviation.

3.6.2 Additionally, full details of the sample and specimen preparation are to be provided including (where applicable):
(a) Catalyst/accelerator or curing agent types and mix ratio.
(b) Weights of resins, and/or reinforcements used.
(c) Casting/laminate dimensions.
(d) Number of layers of reinforcement used.
(e) Curing/post-curing conditions.

3.7 Tests for specific materials

3.7.1 The data requirements in 2.2 and 2.3 for thermoplastic or thermosetting resins or polymers are to be determined in accordance with suitable National or International Standards.

3.7.2 Recognised Standards to which specimens of unreinforced thermoplastic resins are to be tested are listed in Table 14.3.1.

3.7.3 Test standards for unreinforced cast thermosetting resins are given in Table 14.3.2.

3.7.4 The Standards to which laminate specimens of any type are to be tested are listed in Table 14.3.3.

Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-2:1993 – tensile properties are to be measured using extensometry.

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922:2001 or ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393/C393M:06 (short beam) at two representative thicknesses (i.e., 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	ISO 527-4:1997	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	ISO 14125:1998	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min
Interlaminar shear	ISO 14130:1997	
Water absorption	ISO 62:2008	Method 1
Glass content	ISO 1172:1996	

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-4:1997 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

(a) Each skin is to be identical and have a thickness not greater than 21 per cent of the nominal core thickness. For hand laid constructions, each skin is to comprise a lightweight chopped strand mat reinforcement (300 g/m^2) consolidated at a glass content, by weight, of 0,3 against the core, plus the required number of woven reinforcements consolidated, using an isophthalic polyester resin, to give a minimum glass content, by weight, of 0,5.

(b) The method of construction of the sandwich laminate is to reflect the core material manufacturer's instructions for use, i.e., application of bonding paste, surface primer or any other recommended system.

(c) Where vacuum bagging techniques or equivalent systems are used, these will be subject to individual consideration.

(d) All resins and reinforcements are to hold current LR approval.

(e) Curing conditions are to be in accordance with 3.2.3 and 3.2.4.

(f) The dimensions of the test samples should be based on the requirements of ASTM C393 Paragraph 5.1, and the ratio parameters as indicated in ASTM C393 Paragraph 5.2, using a proportional limit stress (F) for the woven roving skins of 130 N/mm^2 and a span (a_2) of not less than 400 mm.

3.8.2 For each type of test sample, the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:

(a) Skin and core thickness, and core type and density.
(b) Resin/catalyst/accelerator ratio.
(c) Skin construction, including types and weight of reinforcements, resin(s), etc.
(d) Details of production method and curing conditions (temperature and times).
(e) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.
(f) Actual span between base supports for each type of test sample.

3.8.3 The following requirements apply to end-grain balsa:

(a) The data requirements of 2.7.1 are to be provided, where applicable, according to suitable National or International Standards.
(b) The balsa is to be tested according to the requirements of 3.8.1.
(c) The test methods for balsa are given in Table 14.3.4.

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845:2006
Tensile properties	ASTM C297/C297M:04 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	ISO 844:2007 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	ISO 1922:2001 Test speed = 1mm/min

3.8.4 The following requirements apply to rigid foams:

(a) The data requirements of 2.7.1 are to be provided in accordance with a suitable National or International Standard.
(b) The foam is to be tested according to the requirements of 3.8.1.
(c) The test methods for rigid foams are to be in accordance with Table 14.3.4.

3.8.5 The following requirements apply to synthetic felt type materials:

(a) The data requirements of 2.10.1 are to be provided according to suitable National or International Standards.
(b) The material is to be tested according to the requirements of 3.8.1, with the following modifications:
    (i) The core of the laminate test sandwich panel is to be prepared with a fibre content as recommended by the manufacturer.
    (ii) The felt fibre/resin ratio is to be stated.
    (iii) The required test thicknesses of the cores are to be changed from 30 mm and 15 mm to 12 mm and 6 mm respectively.
(c) The prepared laminate of the base material is to be of minimum thickness 3,5 mm with a minimum of three layers.
(d) The specified tests on the laminate (*see* 2.10.3) are to be conducted according to the requirements of Table 14.3.3.

3.9 Machinery chocking compounds

3.9.1 Test samples of the cured chock resin are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.11.3.

3.9.2 The specified properties are to be determined as required by Table 14.3.5.

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	ISO 180-2000 Unnotched
Barcol hardness	ASTM D2583-07 or BS 2782 part 10 Method 1001
Compressive strength	ISO 604:2002 Test speed = 1 mm/min
Water absorption	ISO 62:2008 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	ISO 175:1999 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

3.9.3 The percentage linear shrinkage of cured material is to be measured.

3.9.4 Creep is to be measured according to the following method:

(a) A 25 mm x 20 mm diameter parallel faced cylinder is to be pre-loaded against a steel base at 2,5 N/mm^2 or 3,5 N/mm^2, or at the specified higher loading condition, at ambient temperature for 16 hours.
(b) The temperature is to be increased at the rate of 8°C per hour until the service temperature (60°C or 80°C) is reached.
(c) During this time, the creep of the cylinder is to be measured at 15 minute intervals.
(d) The temperature and loading are to be maintained for a minimum of 100 days measuring the creep at intervals of 24 hours.
(e) A plot of creep in mm (linear scale) against time (log scale), together with full experimental details, is to be provided for review by LR.

3.10 Rudder and pintle bearings

3.10.1 All mechanical properties as required by 2.12 are to be measured according to suitable National or International Standards.

3.10.2 Frictional properties are to be determined according to a method agreed with LR.

3.11 Sterntube bearings

3.11.1 The requirements for sterntube bearings are as defined in 2.13.

■ *Section 4* Plastics pipes and fittings

4.1 Scope

4.1.1 This Section gives the general requirements for plastics pipes and fittings, with or without reinforcement, intended for use in the services listed in the relevant Rules dealing with design and construction. Hoses and mechanical couplings are not covered by these requirements.

4.1.2 Pipes and fittings intended for application in Class I, Class II and Class III systems for which there are Rule requirements, are to be manufactured in accordance with the requirements of Section 1 and this Section.

4.1.3 As an alternative to 4.1.2, plastics pipes and fittings which comply with National or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to the requirements of this Section or, alternatively, are approved for a specific application. The survey and certification are however to be carried out in accordance with the requirements of this Section.

4.2 Design requirements

4.2.1 The requirements for design approval are detailed in the relevant Rules.

4.2.2 The design submission is to include a materials list with confirmation that the materials listed have properties and characteristics conforming with those values used in the design submission. As a minimum, the details given should include the following:
(a) Resin.
(b) Accelerator (type and concentration).
(c) Catalyst or curing agent (type and concentration).
(d) Reinforcement.
(e) Cure/post-cure conditions.
(f) Resin/reinforcement ratio.
(g) Wind angle (or lay-up sequence) and orientation.
(h) Dimensions and tolerances.
This submission is to include similar details for the fittings together with a description of the method of attachment of the fittings to the pipes.

4.2.3 Any alteration of the component materials or manufacturing operations from those used in the design submission will necessitate a completely new submission.

4.2.4 If the piping manufacturer anticipates the possible use of alternative materials, these should be listed in the design submission. Proof that the modified product will meet the specified requirements will be needed prior to its use.

4.3 Manufacture

4.3.1 Plastics pipes and fittings intended for use in Class I, Class II and Class III systems are to be manufactured at facilities approved by LR, using materials approved by LR.

4.3.2 A Manufacturing Specification is to be submitted. This is to contain details of the following:
(a) All constituent materials.
(b) Manufacturing procedures such as lay-up sequence or wind angle, the ratios of curing agent to resin and reinforcement to resin, the laminate thickness, the mandrel dwell time (initial cure) and the cure and post-cure conditions.
(c) Quality control procedures including details and frequency of tests on the incoming materials, tests made during production and on the finished piping.
(d) Acceptance standards and tolerances, including all dimensions.
(e) Procedures for cosmetic repair.
(f) System for traceability of the finished piping to the batches of raw materials.
(g) Method of bonding pipes and fittings.

4.3.3 Details of all raw materials are to be submitted for approval and are to be in accordance with the Manufacturing Specification and the design submission.

4.3.4 All batches of raw materials are to be provided with unique identifications by their manufacturers.

4.3.5 No batch of material is to be used later than its date of expiry.

4.3.6 The piping manufacturer is to ensure that all batches of materials are used sequentially.

4.3.7 The piping manufacturer is to maintain records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the Manufacturing Specification.

4.3.8 Records are to be kept of the wind angle and/or the orientation of the reinforcement.

4.3.9 The piping manufacturer is to ensure that each item of piping is traceable to the batch or batches of material used in its manufacture. The unique identifications referred to in 4.3.4 are to be included on all documents.

4.3.10 The curing oven is to be suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

4.3.11 The temperature of the pipe or fitting is to be controlled and recorded by the attachment of suitably placed thermocouples.

4.4 Quality assurance

4.4.1 The piping manufacturer is to have a quality assurance system approved to ISO 9001 or equivalent. This system should ensure that the pipes and fittings are produced with uniform and consistent mechanical and physical properties in accordance with acceptable standards.

4.5 Dimensional tolerances

4.5.1 Dimensions and tolerances are to conform to the Manufacturing Specification.

4.5.2 The wall thicknesses of the pipes are to be measured at intervals around the circumference and along the length in accordance with an appropriate National Standard. The thicknesses are to accord with the Manufacturing Specification.

4.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.6 Composition

4.6.1 The composition of the pipes and fittings is to be in accordance with the Manufacturing Specification.

4.6.2 Where alternative materials are used (*see* 4.2.4), the manufacturer is to demonstrate to the Surveyor's satisfaction, and prior to their introduction, their suitability with respect to the performance of the piping. Otherwise, full testing as specified in 4.7 will be required.

4.7 Testing

4.7.1 For thermoplastic pipes, the polymer manufacturer is to make the following measurements on samples taken from each batch:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

4.7.2 The values obtained are to be certified by the polymer manufacturer.

4.7.3 For reinforced thermoset pipes,the resin manufacturer is to determine, on samples taken from each batch, at least the following:
(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

4.7.4 The values obtained are to comply with the requirements of the Manufacturing Specification.

4.7.5 Where the resin manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 4.7.1 to 4.7.3 as appropriate. The mixed batch is then to be given a unique batch number.

4.7.6 The polymer or resin manufacturer is to demonstrate that each batch of polymer or resin satisfies the requirement for temperature of deflection under load and this is not to be less than 80°C.

4.7.7 These measurements should be repeated on each batch by the piping manufacturer. Where this is not done, LR may require that the tests be made on a random basis by an independent laboratory.

4.7.8 The piping manufacturer is to confirm, by means of tests on at least one batch in twenty, that the temperature of deflection under load exceeds the specified minimum under manufacturing conditions.

4.7.9 Where reinforcements are used, at least the following are to be recorded, where applicable:
(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

4.7.10 All items in 4.7.9 are to comply with the Manufacturing Specification.

4.7.11 The piping manufacturer is to maintain accurate records of resin and glass usage and is to calculate the resin/glass ratio on an ongoing basis.

4.7.12 During manufacture of the piping, apart from the requirements of 4.7.5, 4.7.6 and 4.7.8, tests are to be carried out on the constituents and final product in accordance with Table 14.4.1.

4.7.13 The standards of acceptance are those listed in the Manufacturing Specification approved by LR.

Table 14.4.1 Testing during manufacture of pipes

Component/ operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Wind angle Rate of consumption	Continuous Continuous Continuous
Resin/ reinforcement	Ratio	Continuous
Pipe	Post-cure: temperature of the pipe in oven	Continuous
	Cure level	At least eight per length
	Dimensions	Each length
	Hydraulic pressure test	Each length
	Electrical resistance	Each length (*see* Note)
	Hydraulic bursting test	At Surveyor's discretion
	Axial strength	At Surveyor's discretion

NOTE
Measurements of electrical resistance are only required on piping where the operating conditions given in Pt 5, Ch 12,5.2.4 of the *Rules and Regulations of the Classification of Ships* apply.

4.7.14 At the Surveyor's discretion, sections of pipe are to be subjected to hydraulic bursting tests and/or measurements of axial strength.

4.7.15 If the batch of resin or polymer, or the curing agent, or their ratio is changed during manufacture of a batch of pipes, at least two additional measurements of the gel time are to be carried out during each shift.

4.8 Visual examination

4.8.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.8.2 The pipes are to be reasonably straight and the cut ends are to be square to the axis of the pipe.

4.9 Hydraulic test

4.9.1 Each length of pipe is to be tested at a hydrostatic pressure not less than 1,5 times the rated pressure of the pipe.

4.9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test, endorsed by the Surveyor, will be accepted.

4.10 Repair procedure

4.10.1 Repairs are not allowed, with the exception of minor cosmetic blemishes as detailed in 1.10.1.

4.10.2 A repair procedure for these minor blemishes is to be included in the Manufacturing Specification.

4.11 Identification

4.11.1 All piping is to be identified in such a manner that traceability to all the component materials used in its manufacture is ensured. The Surveyor is to be given full facilities for tracing the material when required.

4.11.2 Pipes and fittings are to be permanently marked by the manufacturer by moulding, hot stamping or by any other suitable method, such as printing, in accordance with 1.11. The markings are to include:
(a) Identification number, *see* 4.11.1.
(b) LR or Lloyd's Register, and the abbreviated name of LR's local office.
(c) Manufacturer's name or trademark.
(d) Pressure rating.
(e) Design standard.
(f) Material system with which the piping is made.
(g) Maximum service temperature.

4.12 Certification

4.12.1 The manufacturer is to provide the Surveyor with copies of the test certificates or shipping statements for all material which has been accepted.

4.12.2 Each test certificate is to contain the following particulars:
(a) Purchaser's name and order number.
(b) If known, the contract number for which the piping is intended.
(c) Address to which piping is despatched.
(d) Type and specification of material.
(e) Description and dimensions.
(f) Identification number, *see* 4.11.1.
(g) Test results.

■ *Section 5* Control of material quality for composite construction

5.1 Scope

5.1.1 This Section gives the general requirements for control of material quality when used in the construction of composite craft.

5.1.2 For composite craft built under the Rules, the survey of materials is to be conducted in accordance with the requirements of Sections 1 to 3 and this Section.

5.2 Design submission

5.2.1 The requirements for design submission are detailed in the appropriate Part of the Rules which includes full information on composite materials.

5.3 Construction

5.3.1 All constructions are to be carried out using materials approved or accepted by LR.

5.3.2 All materials are to be in accordance with the approved construction documentation.

5.3.3 All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.

5.3.4 No batch of material is to be used later than its date of expiry.

5.3.5 The Builder is to ensure that all batches of materials are used systematically and sequentially.

5.3.6 The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.

5.3.7 Records are to be kept of the sequence and orientation of the reinforcements.

5.3.8 The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used. The unique identifications required under 1.11.1 are to be included on all relevant quality control documentation.

5.3.9 Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

5.3.10 The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

5.4 Quality assurance

5.4.1 Where the Builder has a quality assurance system, this is to include the requirements of this Section.

5.5 Dimensional tolerances

5.5.1 Dimensions and tolerances are to conform to the approved construction documentation.

5.5.2 The thicknesses of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

5.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.

5.5.4 Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

5.6 Material composition

5.6.1 The materials, prefabricated sections or components used are to be in accordance with the approved construction documentation.

5.6.2 Where alternative materials are used, these are to be of approved or accepted types and the manufacturer is to demonstrate to the Surveyor's satisfaction, prior to their introduction, their suitability with respect to performance, otherwise full testing as appropriate will be required.

5.7 Material testing

5.7.1 Where so required, the material manufacturer is to provide the purchaser with certificates of conformity for each batch of material supplied, indicating the relevant values specified in 5.7.4 to 5.7.8. These values are to comply with those specified by the approved construction documentation.

5.7.2 Where the Builders do not conduct verification testing of the information indicated in 5.7.4 to 5.7.8, they are to ensure that copies of all certificates of conformity (which must indicate the actual tested values) are obtained for all batches of materials received, and maintain accurate records. The Surveyor may at any time select a sample of a material for testing by an independent, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

5.7.3 The following tests are to be carried out, where applicable, on receipt of any material:

(a) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
(b) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(c) Each batch is to be separately labelled and stored separately.
(d) Each unit, within the batch, is to be labelled with the batch number.
(e) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

5.7.4 For thermosetting resins, reinforced or otherwise, the resin manufacturer is to have determined, on samples taken from each batch, at least the following:
(a) All resins:
 (i) Viscosity.
 (ii) Gel time.
 (iii) Filler content, where applicable.
(b) Polyester and vinylester resins:
 (i) Type (orthophthalic, isophthalic, etc.).
 (ii) Volatiles content.
 (iii) Acid value.
(c) Epoxide resins:
 (i) Free epoxide content.
(d) Phenolic resins:
 (i) Free phenol content.
 (ii) Free formaldehyde content.

5.7.5 For thermoplastics, the polymer manufacturer is to have made the following measurements on samples taken from each batch:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

5.7.6 Where the resin or polymer manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 5.7.4 or 5.7.5 as appropriate. The mixed batch is then to be given a unique batch number.

5.7.7 For reinforcements, the material manufacturer is to have recorded, where applicable, the following for each batch of material:
(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

5.7.8 For core materials, the following properties are to be recorded by the manufacturer for each batch:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.
Together with the following mechanical properties:
In the case of rigid foams:
(g) Compressive strength (stress at maximum load) and modulus of elasticity.
(h) Core shear strength.In the case of end-grain balsa:
(j) Tensile strength (stress at maximum load).
(k) Compressive strength (stress at maximum load) and modulus of elasticity.

5.7.9 During construction, tests are to be carried out on the constituents and final product in accordance with Table 14.5.1.

5.7.10 The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable.

5.7.11 Laminate fibre content is to be determined at the request of the Surveyor, in particular where the thickness measured does not correlate with the specified fibre content, by weight. This will, in general, result in additional reinforcement being required.

5.7.12 If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.

Table 14.5.1 Testing during construction

Component/operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Orientation Rate of consumption	Continuous Continuous Continuous
Resin/reinforcement	Ratio	Continuous
Construction	Temperature during cure/post cure Dimensions Cure level (Barcol) against resin manufacturer's specification Laminate thickness Laminate fibre content	Continuous Continuous against approved construction documentation At least one per square metre Continuous against material usage and approved construction documentation (*see also* 5.5.2 to 5.5.4) At the Surveyor's request (*see* 5.7.11)

5.8 Visual examination

5.8.1 All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

5.9 Repair procedure

5.9.1 Repairs of minor cosmetic blemishes are permitted providing that these are brought to the attention of the Surveyor.

5.9.2 A repair procedure for these minor blemishes is to be included in the agreed quality control procedures.

5.9.3 Structural repairs are subject to individual consideration and full written details must be approved by the plan approval office prior to introduction.

5.10 Material identification

5.10.1 Records of the construction are to be kept in such a manner that traceability of all the component materials used is ensured. The Surveyor is to be given full facilities for tracing the material's origin when required.

5.10.2 Small representative samples of each batch of material are to be retained, these being suitably labelled to ensure traceability.

5.10.3 When so requested by the Surveyor, the Builder is to provide copies of all test data and/or manufacturers' certificates of conformity appertaining to any material used.

5.11 Minimum tested requirements for material approval

5.11.1 This Section provides the minimum property values required of a material for approval or acceptance by LR and are applicable to materials cured under ambient conditions.

5.11.2 **Gel coat resins**. When the cast resin is tested according to the requirements of 2.3, Table 14.5.2 gives the minimum values for the respective properties.

5.11.3 **Laminating resins**. When tested according to the requirements of 2.3 and 2.4, Tables 14.5.3 and 14.5.4 give the minimum properties for the cast resin and chopped strand mat laminate respectively.

5.11.4 When tested to the requirements of 2.4 for reinforcements, Table 14.5.5 gives the minimum properties for laminates.

5.11.5 Alternatively, materials may be approved by use of the actual tested values whereby the approval value shall equal the mean of the tested values minus twice the standard deviation of a minimum of five tested values.

Table 14.5.2 Gel coat resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,5%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Water absorption	70 mg (max)

Table 14.5.3 Laminating resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,0%
Modulus of elasticity in tension	As measured
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
NOTE These minimum values are for the recommended glass content by weight of 0,3.	

5.12 Closed cell foams for core construction based on PVC or polyurethane

5.12.1 Table 14.5.6 gives minimum values for closed cell forms for core construction based on PVC or polyurethane.

5.12.2 Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0,5 N/mm^2 is to be achieved.

5.13 End-grain balsa

5.13.1 Table 14.5.7 gives the minimum property requirement for end-grain balsa.

5.14 Synthetic chocking compounds

5.14.1 After 1000 hours the chocking resin must be stabilised and maximum creep is to be less than or equal to 0,2 per cent.

Table 14.5.4 Laminating resins, minimum values for properties for CSM laminate at 0,3 glass fraction by weight

Properties	Minimum value
Tensile strength (stress at maximum load)	90 N/mm^2
Secant modulus at 0,25% and 0,5% strain respectively	6,9 kN/mm^2
Compressive strength (stress at maximum load)	125 N/mm^2
Compressive modulus	6,4 kN/mm^2
Flexural strength (stress at maximum load)	160 N/mm^2
Modulus of elasticity in flexure	5,7 kN/mm^2
Apparent interlaminar shear strength (*see* Note)	18 N/mm^2
Fibre content	As measured (0,3)
Water absorption	70 mg (max)

NOTE
Applicable only to the special test for environmental control resins.

5.14.2 Compliance with 5.14.1 is to be demonstrated at the time of chocking compound approval for a specified cure/post-cure schedule. The Izod, barcol, compression, and water and oil absorption are additionally to be determined for the creep tested cure/post cure schedule.

5.14.3 Confirmation of creep, barcol and compression will be required for cure/post-cure conditions which differ from those shown on the product approval certificate.

5.15 Other materials

5.15.1 All other materials will be subject to special consideration.

Table 14.5.5 Laminates, minimum property requirements

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	$200G_c + 30$
	Modulus of elasticity in tension (kN/mm^2)	$15G_c + 2,4$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c – 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c – 0,5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 – 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 – 114G_c + 39$
Chopped strand mat	Flexural (stress at maximum load) (N/mm^2)	$502G_c^2 + 114,6$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,7$
All	Flexural strength (stress at maximum load) (N/mm^2)	$502G_c^2 + 106,8$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,2$
	Compressive strength (stress at maximum load) (N/mm^2)	$150G_c + 72$
	Compressive modulus (kN/mm^2)	$40G_c – 6$
	Interlaminar shear strength (N/mm^2)	$22 – 13,5G_c$ (min 15)
	Water absorption (mg)	70 (maximum)
	Glass content (% by weight)	As measured

NOTES
1. After water immersion, the values shall be a minimum of 75% of the above.
2. Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction.
3. G_c = glass fraction by weight.

Table 14.5.6 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density kg/m^3	Strength (stress at maximum load) (N/mm^2)			Modulus of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 14.5.7 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (stress at maximum load) (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,0	0,35	9,00	0,44	1,10	2300	35,2	105
144	10,6	0,57	14,6	0,70	1,64	3900	67,8	129
176	12,8	0,68	20,5	0,80	2,00	5300	89,6	145

Rules and Regulations for the Classification of Offshore Units

Part 3
Functional Unit Types and Special Features

July 2014

Lloyd's Register

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■ *Section 1* Rule application

1.1 General

1.1.1 This Part is applicable to all types of offshore units as defined in Pt 1, Ch 2,2. Units of unconventional type or form will receive individual consideration based on the general standards of these Rules.

1.1.2 In addition to the Rule requirements for Classification, attention is to be given to the relevant statutory Regulations of the National Administrations in the area of operation and also the country of registration, as applicable, *see* Pt 1, Ch 2,1.

1.1.3 The requirements stated in this Part for the particular unit types and special features class notations are supplementary to those stated in other Parts of these Rules.

■ *Section 2* Information required

2.1 General

2.1.1 General requirements regarding information required are given in Pt 3, Ch 1,5 of the Rules for Ships, which are to be complied with as applicable.

2.1.2 Additional plans, documents and data are to be submitted for approval and information as required by the relevant Parts of these Rules, together with the additional information related to the unit type and its specialised function as defined in this Part.

2.1.3 Where an **OIWS** class notation, for In-water Survey, is to be assigned, *see* Pt 1, Ch 2, plans and information covering the following items are to be submitted as applicable:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets is to be verified with the unit afloat.
- Details and arrangements for inspecting thrusters and sea chests.
- Details showing how stern bush clearances are to be inspected and measured with the unit afloat.
- Details of arrangements for servicing and unshipping thrusters.
- Details and arrangements for servicing sea inlet valves and checking sea chests.
- Details of underwater marking, *see* Section 6.
- Details of coating systems and cathodic protection, *see* Part 8.

2.1.4 Approved plans and information covering the items detailed in 2.1.3 are to be placed on board the unit.

2.2 Construction booklet

2.2.1 A construction booklet including a set of plans showing the exact location and extent of application of different grades and mechanical properties of structural materials, together with welding procedures employed for primary structure, is to be submitted for approval and a copy to be placed aboard the unit. Any other relevant construction information is to be included in the booklet, including restrictions or prohibitions regarding repairs or modifications.

2.2.2 Similar information is to be provided when aluminium alloy or other materials are used in the construction of the unit.

2.2.3 Copies of the main scantlings plans and details of the corrosion control system fitted are to be placed on board the unit.

■ *Section 3* Operations manual

3.1 General

3.1.1 A manual of operating instructions is to be prepared and placed on board each unit and should be made readily available to all concerned in the safe operation of the unit, *see also* 3.2.4.

3.1.2 It is the responsibility of the Owner to provide in the Operations Manual all the necessary instructions and limits on the operation of the unit to ensure that the environmental and operating loading conditions on which the Classification is based will not be exceeded in service.

3.1.3 Where a National Administration has a specific requirement regarding the contents of the Operations Manual, it is the responsibility of the Owner to comply with such Regulations.

3.1.4 The Operations Manual is to be submitted when the plans of the unit are being approved by LR. The Operations Manual will be reviewed in respect of those aspects covered by Classification only.

3.1.5 Where a unit is modified during its service life, it is the Owner's responsibility to update the Operations Manual, as necessary, and advise LR of any changes which may affect the Classification of the installation.

3.2 Information to be included

3.2.1 In general, the Operations Manual should include the following minimum information, as applicable:

- General description and particulars of the unit.
- Chain of command and general responsibilities during all normal operating modes and emergency operations.
- Limiting design data for each approved mode of operation, including design and variable loading, draughts, air gap, wave height, wave period, wind, current, minimum sea and air temperatures, assumed sea bed conditions, orientation, and any other applicable environmental factors, such as icing.
- A description of any inherent operational limitations for each mode of operation and for each change in mode of operation. For ship units and other surface type units, *see also* 3.2.4.
- Permissible deck loading plan.
- General arrangement plans showing watertight and weathertight boundaries.
- The location and type of watertight and weathertight closures, vents, air pipes, etc., and the location of downflooding points.
- The location, type and weights of permanent ballast installed on the unit.
- A description of the signals used in the general alarm, public address, fire and gas alarm systems.
- Hydrostatic curves, or equivalent data.
- A capacity plan showing the capacities and the centres of gravity of tanks and bulk material stowage spaces.
- Tank sounding tables or curves showing capacities, the centres of gravity in graduated intervals and the free surface data of each tank.
- Plans and description of the ballast system and instructions for ballasting.
- Plan indicating hazardous areas.
- Fire control and safety/evacuation plans.
- Lightship data based on the results of an inclining experiment, etc.
- Stability information in the form of maximum KG versus draught curve, or other suitable parameters, based upon compliance with the required intact and damaged stability criteria.
- Representative examples of loading conditions for each approved mode of operation, together with the means for evaluation of other loading conditions. For ship units and other surface type units, *see also* 3.2.4.
- Positional mooring system, and limiting conditions of operation.
- Description and limitations of any onboard computer used in operations such as ballasting, anchoring, dynamic positioning and in trim and stability calculations.
- Plan of towing arrangements and limiting conditions of operation.
- Description of the main power system and limiting conditions of operation.
- Details of emergency shut-down procedures.
- Identification of the helicopter used for the design of the helicopter deck.

3.2.2 Instructions for the operation of the unit are to include precautions to be taken in adverse weather, changing mode of operation, any inherent limitations of operations, approximate time required for meeting severe storm conditions, mooring pattern/heading.

3.2.3 For self-elevating units, the manual is to include instructions on safety during jacking-up and jacking-down of the hull, over the period of time that the unit is in the elevated position, and during extreme weather conditions while in transit, including the positioning and securing of legs, cantilever drill floor structures and heavy cargo and equipment which might shift position. Limitations on the maximum permissible rigid body motions of the unit, and allowable sea states whilst elevating or lowering the legs.

3.2.4 For ship units and other surface type units, sufficient information is to be supplied to the Master/Operator to enable him to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the unit's structure. This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument, *see* Pt 1, Ch 2,1. The Loading Manual may form part of the Operations Manual, or may be a separate document.

■ *Section 4* Materials

4.1 General

4.1.1 The Rules relate in general to the construction of steel units of welded construction, although consideration will be given to the use of other materials. For concrete structures, *see* Part 9.

4.1.2 The materials used for the construction and repair of units and installed machinery are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

4.1.3 As an alternative, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

4.1.4 Materials for specialised areas of the unit, related to its function or special features class notation, are to be in accordance with the relevant Chapters of this Part, *see also* 4.3.

4.2 Material selection

4.2.1 Materials are to be selected in accordance with the requirements of the design in respect of static strength, fatigue strength, fracture resistance and corrosion resistance, as appropriate.

4.2.2 The grades of steel to be used in the construction of the unit are to be related to the thickness of the material, the location on the unit and the minimum design temperature, *see* 4.4.

4.2.3 The grades of steel to be used for the drilling plant and the production and process plant are to be in accordance with the requirements of Chapters 7 and 8 respectively.

4.2.4 The effects of corrosion, either from the environment or from the products handled on the unit or its associated plant and machinery, are to be taken into account in the design.

4.3 Structural categories

4.3.1 The structural categories for the hull construction and the corresponding grades of steel used in the structure are to be in accordance with Pt 4, Ch 2.

4.3.2 The structural categories for supporting structures for drilling plant and production and process plant are to be in accordance with Chapters 7 and 8 respectively.

4.4 Minimum design temperature

4.4.1 The minimum design temperature is a reference temperature used as a criterion for the selection of the grade of steel to be used.

4.4.2 The minimum design air and sea temperatures for exposed structure are to be taken as the lowest daily mean temperature for the unit's proposed area of operation, based on a return period of:
(a) 50 years for Mobile Offshore Units.
(b) 100 years for Floating Offshore Installations at a fixed location.

The temperature is to be rounded down to the nearest degree Celsius. Consideration is to be given to the minimum temperature at the ship yard during construction and testing, and along transit routes for any voyage of the unit from one geographical location to another. For LNG installations, consideration of the minimum design temperature is required where the hull plating forms part of the secondary barrier.

4.4.3 The minimum design temperature (MDT) for drilling plant and production and process plant is to be defined by the designers/Builders, but when appropriate the MDT should not be higher than the MDT for the exposed structure defined in 4.4.2.

4.5 Aluminium structure, fittings and paint

4.5.1 The use of aluminium alloy is permitted for secondary structure, as defined in Pt 4, Ch 2.

4.5.2 Where aluminium alloy is used for secondary structure, the material is to conform with the requirements of Chapter 8 of the Rules for Materials.

4.5.3 The use of aluminium alloy for primary structure will be specially considered.

4.5.4 Where aluminium alloy is used in the construction of fire divisions, it is to be suitably insulated in accordance with the requirements of the appropriate National Administration, *see* 1.1.2.

4.5.5 Since aluminium alloys may, under certain circumstances, give rise to incendive sparking on impact with steel, the following requirements are to be complied with:
(a) Aluminium fittings in tanks used for the storage of oil, and in cofferdams and pump-rooms in oil storage units are to be avoided wherever possible.
(b) Where fitted, aluminium fittings, anodes and supports in tanks used for the storage of oil, cofferdams and pump-rooms are to satisfy the requirements specified in Pt 8, Ch 2,5 for aluminium anodes.
(c) The danger of mistaking aluminium anodes for zinc anodes must be emphasised. This gives rise to increased hazard if aluminium anodes are inadvertently fitted in unsuitable locations.
(d) The undersides of heavy portable aluminium structures such as gangways, etc., are to be protected by means of hard plastic or wood covers, in order to avoid the creation of smears when dragged or rubbed across steel, which if subsequently struck, may create an incendive spark. It is recommended that such protection be permanently and securely attached to the structures.
(e) Aluminium is not to be used in hazardous areas on drilling units and production and oil storage units unless adequately protected, and full details submitted for approval. Aluminium is not to be used for hatch covers to any openings to oil storage tanks.

4.5.6 For permissible locations of aluminium anodes, *see* Pt 8, Ch 2,5.

4.5.7 The use of aluminium paint is to comply with the requirements of Pt 8, Ch 3,1.

Section 5
Corrosion control

5.1 General

5.1.1 The corrosion control of steelwork on all units is to be in accordance with Part 8. The corrosion protection of mooring systems is to comply with Chapter 10.

5.1.2 The basic Rule scantlings of the external submerged steel structure of units which are derived from Pt 4, Ch 6 assume that appropriate coatings and an external cathodic protection system will be fitted. If the corrosion protection system of the submerged structure is not in accordance with the Rules the scantlings are to be suitably increased.

5.1.3 Ship units and other surface type units which are assigned an **OIWS** notation are to be fitted with external cathodic protection and external coating systems in accordance with Part 8.

Section 6
Underwater marking

6.1 General

6.1.1 Where an **OIWS** notation, for In-water Survey, is to be assigned, *see* Pt 1, Ch 2, the requirements of this Section are to be complied with.

6.1.2 The underwater structure of a unit intended to be surveyed on an In-water basis should have its main frames, bulkheads and joints, etc., clearly identified by suitable marking. Details are to be submitted for approval.

6.1.3 Marking should consist of raised lines, numerals and letters. In general, marking by welding is not to be used on ship units and other surface type units.

6.1.4 If marking is to be carried out by welding, the welds should be made with continuous runs and the quality of the workmanship should be to an equivalent standard as the main hull structure. Substantial runs should be laid, continuously, using large diameter electrodes and avoiding light runs as these are more likely to promote cracking. Sharp corners in the letters are to be avoided. Marking by welding is not permitted in highly stressed areas or over existing butts or seams. The welding procedures and consumables are to be submitted for approval.

6.1.5 On steel of Grade D or E or on higher tensile steel, low hydrogen electrodes should be used of a grade suitable for the steel. In the case of higher tensile steel, *see* Ch 3,3 of the Rules for Materials, pre-heating to about 100°C should be adopted.

6.2 Design features

6.2.1 The following features are to be incorporated into the unit's design, where applicable, in order to facilitate the underwater inspection. When verified, they will be noted in the unit's classification for reference at subsequent surveys.

6.2.2 **Stern bearing**. For self-propelled units, means are to be provided for ascertaining that the seal assembly on oil-lubricated bearings is intact and for verifying that the clearance or weardown of the stern bearing is not excessive. For oil-lubricated bearings, this may only require accurate oil loss rate records and a check of the oil for contamination by sea-water or white metal. For wood or rubber bearings, an opening in the top of the rope guard and a suitable gauge or wedge would be sufficient for checking the clearance by a diver. For oil-lubricated metal stern bearings, weardown may be checked by external measurements between an exposed part of the seal unit and the stern tube bossing, or by use of the unit's weardown gauge, where the gauge wells are located outboard of the seals, or the unit can be tipped. For use of the weardown gauges, up-to-date records of the base depths are to be maintained on board. Whenever the stainless steel seal sleeve is renewed or machined, the base readings for the weardown gauge are to be re-established and noted in the unit's records and in the survey report.

6.2.3 **Rudder bearings**. For self-propelled units with rudders, means and access are to be provided for determining the condition and clearance of the rudder bearings, and for verifying that all parts of the pintle and gudgeon assemblies are intact and secure. This may require bolted access plates and a measuring arrangement.

6.2.4 **Sea suctions**. Means are to be provided to enable the diver to confirm that the sea suction openings are clear. Hinged sea suction grids would facilitate this operation.

6.2.5 **Sea valves**. For the Dry-docking Survey (Underwater Inspection) associated with the Special Survey, means must be provided to examine any sea valve.

6.2.6 Alternative arrangements to facilitate In-water Surveys will be considered; details are to be submitted to LR for approval.

Section 7
Permanent means of access

7.1 General

7.1.1 Each space within the unit should be provided with at least one permanent means of access to enable, throughout the life of a unit, overall and close-up inspections and thickness measurements of the unit's structures to be carried out by LR, the company, and the unit's personnel and others, as necessary. Such means of access should comply with the provisions of MODU Code 2009, paragraph 2.2 and with the Technical provisions for means of access for inspections, adopted by the Maritime Safety Committee by Resolution MSC.133(76), as may be amended by the IMO.

Section 1
General

1.1 Application

1.1.1 The requirements of this Chapter apply to all drilling units engaged in drilling operations for the exploration and exploitation of petroleum, gas or other resources beneath the sea bed.

1.1.2 Surface type units are to comply with this Chapter, but reference should also be made to Pt 4, Ch 4,4.

1.1.3 Units engaged in rock drilling or other similar work operations not related to petroleum or gas resources will be specially considered but should comply with the general requirements of this Chapter as applicable to the unit.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations:

Mobile offshore drilling unit; or
Drill ship.

Other type notations may be assigned when considered appropriate by the Classification Committee.

1.2.3 Drilling units with an installed drilling plant facility which comply with the requirements of Chapter 7 will be eligible for the assignment of the special features class notation **DRILL**.

1.2.4 When a **DRILL** notation is not assigned to a unit with a drilling plant facility, classification of the unit will be subject to the drilling plant being certified by LR, or by another acceptable organisation.

1.2.5 When, at the request of an Owner, a unit is to be verified in accordance with the Regulations of a National Administration, a descriptive note will be included in the ClassDirect Live website.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- Structural arrangements of the unit related to drilling operations.
- Supporting structures for drilling equipment, bulk storage and raw water towers.
- Drill floor and derrick substructure.
- Drilling cantilevers.
- Structural arrangements in way of drilling wells.
- Structural mud tanks or pits.
- Deckhouses and modules related to drilling operations.
- Pipe racks and supports.
- Hazardous areas and ventilation.
- Pollution prevention.

1.4 Installation layout and safety

1.4.1 In principle, drilling units are to be divided into main functional areas to ensure that the following areas are separated and protected from each other:

(a) Drilling area:
  - Drill floor area
  - Mud circulation and treatment area.

(b) Auxiliary equipment area.

(c) Living quarters' area.

1.4.2 Attention is to be given to the relevant Statutory Regulations for fire safety of the National Administration in the country of registration and the areas of operation as applicable, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.4.3 Additional requirements for safety systems and hazardous areas are given in Part 7.

1.4.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from the drilling area.

1.5 Plans and data submission

1.5.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

Section 2
Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information, as required by Ch 1,2 and Pt 4, Ch 1, the following additional plans and information are to be submitted:

- General arrangement plans.
- General arrangement plans of drilling derrick and equipment.
- Structural plans of drill floor, drilling derrick supports, substructure, drilling equipment supports, pipe rack and supports.
- Structural arrangements in way of drilling wells.
- Movable drilling cantilevers and skid beams.
- Hull supporting structures.
- Hull structural plans of mud compartments, mud tanks and pump-rooms.
- Deckhouses and modules.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of Part 4 taking into account the drilling structures and applied equipment weights and forces introduced by the drilling operations. Attention should be paid to loads resulting from hull flexural effects at support points. For surface type units, *see also* Ch 1,1.

2.2.2 The design loadings for the strength of the drill floor and substructure are to be defined by the designers/Builders and calculations are to be submitted.

2.2.3 Strength calculations are to be submitted for moveable drilling cantilevers, skid beams and their supports. The clearances between the cantilever support claw and the skidding guides is the responsibility of the designers/Builders.

2.2.4 The maximum reaction forces from the drilling derrick are to be determined from an acceptable National Code or Standard and should take into account the load effects from vessel motions, the drillpipe setback, hook load, rotary table and tensioning equipment, *see* Chapter 7.

2.2.5 When the unit is to operate in an area which could result in the build-up of ice on the drilling derrick and other structures, the effects of ice loading is to be included in the calculations, *see* Pt 4, Ch 3,4.

2.2.6 The local structure should be reinforced for the component forces from drilling equipment and tensioner forces, and the design loadings are to be determined in accordance with Chapter 7.

2.2.7 The supporting structure and attachments under large equipment items are also to be designed for the emergency condition as defined in Ch 8,1.4.

2.2.8 Attention should be paid to the capability of support structures to withstand buckling, *see* Pt 4, Ch 5,4.

2.2.9 When blast walls are fitted on the unit, the primary supporting structure in way of the blast walls is to be designed for the maximum design blast force with the permissible stress levels in accordance with Pt 4, Ch 5,2.1.1(c).

2.3 Well structure

2.3.1 The primary hull strength of the unit is to be maintained in way of drilling wells and other large deck openings and suitable compensation is to be fitted as necessary. For surface type units the minimum hull modulus in way of the drilling well is to satisfy the Rule requirements for longitudinal strength.

2.3.2 Arrangements are to be made to ensure continuity of strength at the ends of longitudinal and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large, suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and bulkheads.

2.3.3 The boundary bulkheads of drilling wells are to be designed for the maximum forces imposed by the drilling operations. The minimum scantlings of well bulkheads are to comply with the requirements for tank bulkheads in Pt 4, Ch 6,7 using the load head measured to the top of the well, but in no case is the well plating to have a thickness less than 9,0 mm.

2.4 Permissible stresses

2.4.1 In general, the permissible stresses in the structure in operating, transit and survival conditions are to comply with Pt 4, Ch 5,2 but the minimum scantlings of the local structure are to comply with Pt 4, Ch 6. For surface type units, *see also* Pt 4, Ch 4,4.

2.4.2 Permissible stresses for lattice type structures may be determined from an acceptable code, *see* Part 3, Appendix A.

2.5 Mud tanks

2.5.1 The scantlings of structural mud tanks are not to be less than those required for tanks in Pt 4, Ch 6,7 using the design density of the mud. In no case is the relative density of wet mud to be taken less than 2,2 unless otherwise agreed with LR.

2.5.2 Divisions in mud tanks or pits are to be designed for one-sided loading and the scantlings are to comply with the requirements for tanks in Pt 4, Ch 6,7.

2.6 Deckhouses and modules

2.6.1 The scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9. Where deckhouses support equipment loads they are to be suitably reinforced.

2.6.2 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.6.3 When containerised modules can be subjected to wave loading the scantlings are not to be less than required by 2.6.1.

2.7 Pipe racks

2.7.1 The pipe rack is to be designed for the following normal operating loads as applicable:

- Gravity loads.
- Maximum dynamic loads due to wave-induced unit motions.
- Direct wind loads.
- Ice and snow loads.

2.7.2 The pipe rack supports are also to be designed for an emergency condition as defined in Ch 8,1.4.

2.7.3 In general, the pipe rack supports are to be aligned with the primary under-deck structure. Where this is not practicable additional under-deck supports are to be fitted. Deck girders and under-deck supports are to comply with Pt 4, Ch 6,4.

2.7.4 In the emergency condition arrangements are to be made to restrain the pipes in their stowed position and details are to be submitted for approval.

2.8 Bulk storage vessels

2.8.1 Free standing bulk storage vessels are to comply with the requirements of Ch 8,4.

2.8.2 The deck supports under free standing bulk storage vessels are to comply with the requirements for local structure in Pt 4, Ch 6, taking into account the maximum design reaction forces.

2.8.3 Where bulk storage vessels penetrate watertight decks and can be subjected to external hydrostatic pressure due to progressive flooding in hull damage conditions, the bulk storage vessel is to be suitably reinforced and the permissible stress is not to exceed the code stress in accordance with Ch 8,4.

2.9 Watertight and weathertight integrity

2.9.1 The general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

2.9.2 The integrity of the weather deck is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise such items are to be enclosed in superstructures or deckhouses fully complying with the Rules. Full details are to be submitted for approval.

2.9.3 Where items of plant equipment or pipes penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval.

2.9.4 Where free-standing bulk storage vessels penetrate watertight decks or flats the arrangements to ensure watertight integrity will be specially considered, *see* 2.8.3.

■ *Section 3* Hazardous areas and ventilation

3.1 Hazardous areas and ventilation

3.1.1 For the application of hazardous area classification and ventilation requirements for drilling units, *see* Pt 7, Ch 2.

3.1.2 Ventilation in the vicinity of the mud tanks is to be specially considered to ensure adequate dilution of any dangerous gases.

3.1.3 For units using oil-based mud, the tanks are to be provided with special ventilating arrangements, and for open systems the maximum oil density in the air above the tanks is not to exceed 5 mg/m^3. Ventilation of the enclosed spaces with open active mud tanks or pits is to be arranged for at least 30 air changes per hour for personnel comfort.

■ *Section 4* Pollution prevention

4.1 General

4.1.1 When oil is added to the drilling mud, provision is to be made to limit the spread of oil on the unit, and to prevent the discharge of oil or oily residues into the sea by the provision of de-oilers and suitably alarmed oil monitoring devices.

4.1.2 Drilling bell nipples, flow lines, ditches, shale shakers, mud rooms and mud tanks and pumps are to be designed for maximum volume throughput without spillage. Equipment requiring maintenance is to have adequate spillage catchment arrangements.

4.1.3 Pollution prevention arrangements should be such that the unit can comply with the requirements of the relevant National Administrations in the country of registration and in the area of operation, as applicable.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to units engaged in production and/or crude oil or liquefied gas bulk storage and offloading at offshore locations. Production units have specialised structures and plant installed on board for production and/or processing crude oil or gas.

In general, oil storage units have integral tanks for the storage of crude oil in bulk and the Rules are primarily intended for units which are to store flammable liquids having a flash point not exceeding 60°C (closed-cup test).

Ship units with bulk storage tanks for liquefied gases or liquid chemicals are to comply with 1.1.4 and 1.1.5 respectively. Other unit types with bulk storage tanks for liquefied gases or liquid chemicals will be specially considered on the basis of 1.1.4 and 1.1.5 as applicable.

1.1.2 Column-stabilised and self-elevating units which are intended to operate only at a fixed offshore location are to comply with this Chapter, but reference should be made to Ch 1,1.

1.1.3 Ship units are to comply with this Chapter, in addition to Part 10.

1.1.4 Ship units required for the storage of liquefied gases in bulk are to comply with Part 11, in addition to 1.1.3.

1.1.5 Ship units required for the storage of liquid chemicals in bulk are to comply with 1.1.3, and in general with the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code), as interpreted by LR.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations:

- Production unit.
- Floating production unit.
- Floating production and oil storage unit.
- Oil storage unit.

Other type notations may be assigned when considered appropriate by the Classification Committee.

1.2.3 Type class notations for units with bulk storage tanks for liquefied gases or liquid chemicals will be specially considered by the Classification Committee.

1.2.4 When a unit is to be verified in accordance with Regulations of a Coastal State Authority/National Administration, an additional class notation may be assigned in accordance with Pt 1, Ch 2.

1.2.5 Production units with an installed process plant facility, which comply with the requirements of Chapter 8, will be eligible for the assignment of the special features class notation **PPF**. For units with riser systems, *see also* Chapter 12.

1.2.6 When a **PPF** notation is not assigned to a unit with a process plant facility, classification of the unit will be subject to the process plant being certified by LR, or by another acceptable organisation.

1.2.7 Production units without an installed process plant facility are to comply with the general requirements of Chapter 8 as applicable.

1.2.8 Units with an installed drilling plant facility, which comply with the requirements of Chapter 7, will be eligible for the assignment of the special features class notation **DRILL**.

1.2.9 When a **DRILL** notation is not assigned to a unit with a drilling plant facility, classification of the unit will be subject to the drilling plant being certified by LR, or by another acceptable organisation.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- General arrangement.
- Structural arrangement of the unit.
- Supporting structures below production and process plant equipment, flare structures, and marine risers.
- Deckhouses and modules related to production operations.
- Loading of hot oils.
- Structural arrangement of oil storage tanks, cofferdams and pump-rooms.
- Access arrangements.
- Compartment minimum thickness.
- Hazardous areas and ventilation.
- Pollution prevention.

1.3.2 Where the unit is fitted with drilling equipment, the requirements of Chapter 2 are to be complied with.

1.4 Installation layout and safety

1.4.1 In principle, production units are to be divided into main functional areas to ensure that the following areas as applicable are separated and protected from each other:
(a) Production area:
- Wellhead area.
- Processing area.

(b) Drilling area:
- Drill floor area.
- Mud circulation and treatment area.

(c) Auxiliary equipment area.
(d) Living quarters' area.

1.4.2 Attention is to be given to the relevant Statutory Regulations for fire safety of the National Administrations in the country of registration and/or in the area of operation as applicable, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.4.3 Additional requirements for safety systems and hazardous areas are given in Part 7.

1.4.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from production and wellhead areas.

1.4.5 In general, production units with crude oil bulk storage tanks are to be designed so that the arrangement and separation of living quarters, storage tanks, machinery rooms, etc., are arranged in accordance with the *International Convention for the Safety of Life at Sea, 1974* as amended, Regulations 11-2/56. Where this is not practicable owing to the unconventional design construction of the unit, special consideration will be given to other arrangements which provide equivalent separation and protection. *See also* Pt 1, Ch 2,1.1.11. For ship units and surface type units with crude oil bulk storage tanks, the general arrangement and separation of spaces are to comply with Pt 4, Ch 9 of the Rules for Ships, or equivalent arrangements provided.

1.4.6 The position of the process plant in relation to storage tanks for crude oil, gas or other products will be specially considered, and consideration will be given to the requirements with regard to the provision of effective separation, methods of storage, loading and discharging arrangements.

1.4.7 Provision is to be made for purging, gas freeing, inerting or otherwise rendering safe crude oil bulk storage tanks, process plant and process storage facilities before the unit moves to a new location.

■ *Section 2* **Structure**

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by Ch 1,2 and Pt 4, Ch 1 the following additional plans and information are to be submitted:
- General arrangement.
- General arrangement plans of the production plant and process equipment layout.
- Structural supports below plant equipment.
- Structural plans of crude oil tanks, ballast tanks, cofferdams, void spaces, pump-rooms and machinery spaces.
- Deckhouses and modules.

2.1.2 When the unit is fitted with drilling equipment, the additional plans required by Ch 2,2 are to be submitted as applicable.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of Part 4, taking into account the type of unit, the imposed equipment weights and forces from the production and process plant, mooring forces and drilling plant, when fitted. Attention should be paid to loads resulting from hull flexural effects at support points.

2.2.2 The supporting structure below equipment is to be designed for all operating conditions and the maximum design loadings from the production and process plant imposed on the structure are to be determined in accordance with Chapter 8.

2.2.3 Decks and other under-deck structure supporting the plant are to be suitable for the local loads at plant support points and an agreed uniformly distributed load acting on the deck, *see* Pt 4, Ch 6,2. The structure in way of marine risers is to be suitably reinforced for the imposed loads.

2.2.4 In general, all seatings, platform decks, girders and pillars supporting plant items are to be arranged to align with the main hull structure, which is to be suitably reinforced, where necessary, to carry the appropriate loads. Attention should be paid to the capability of support structures to withstand buckling, *see* Pt 4, Ch 5,4.

2.2.5 The strength of the unit in way of openings is to be maintained. Structure in way of openings of unusual size, configuration and/or shape may require investigation by structural analysis when requested by LR.

2.2.6 Insert plates of adequate thickness and steel grade, appropriate to the stress concentrations and locations, may be required in way of openings and structural discontinuities in primary structure.

2.2.7 Critical joints depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing) are to be avoided wherever possible. Where unavoidable, plate material with suitable through-thickness properties will be required, *see* Ch 3,8 of the Rules for Materials and Pt 4, Ch 2,4.1.3.

2.2.8 When blast walls are fitted on the unit, the primary supporting structure in way of the blast walls is to be designed for the maximum design blast force with the permissible stress levels in accordance with Pt 4, Ch 5,2.1.1(c).

2.2.9 Turret structures, swivel stacks, mooring arms and yoke structures, etc., are to comply with the requirements of Chapter 13.

2.3 Drilling structures

2.3.1 When a unit is fitted with a drilling derrick, the requirements of Ch 2,2 are to be complied with, as applicable.

2.3.2 The design loadings for the strength of the drill floor and substructure are to be defined by the designer/Builders and calculations are to be submitted.

2.4 Permissible stresses

2.4.1 In general, the permissible stresses in the structure in operating, transit and survival conditions are to comply with Pt 4, Ch 5,2 but the minimum scantlings of the local structure are to comply with Pt 4, Ch 6. For ship units, *see* Part 10. For other surface type units, *see* Pt 4, Ch 4.

2.4.2 Permissible stresses for lattice type structures may be determined for an acceptable Code, *see* Appendix A.

2.5 Well structure

2.5.1 The primary hull strength of the unit is to be maintained in way of moonpools, turret openings, drilling wells and other large deck openings and suitable compensation is to be fitted, as necessary. For ship units and other surface type units, the continuity of longitudinal material is to be maintained, as far as is practicable, in way of turret openings and wells and the minimum hull modulus is to satisfy the Rule requirements for longitudinal strength.

2.5.2 Arrangements are to be made to ensure continuity of strength at the ends of moonpools and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large, suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and bulkheads.

2.5.3 Circumturret bulkheads and the boundary bulkheads of moonpools and drilling wells are to be designed for the maximum forces imposed on the structure. For ship units, *see* Part 10. For other surface type units, *see* Pt 4, Ch 4,4. For other unit types, *see* Pt 4, Ch 6.

2.6 Mud tanks

2.6.1 The scantlings of structural mud tanks are not to be less than those required for tanks in Pt 4, Ch 6,7 using the design density of the mud. In no case is the relative density of wet mud to be taken less than 2,2 unless agreed otherwise with LR.

2.6.2 Divisions in mud tanks or pits are to be designed for one-sided loading and the scantlings are to comply with the requirements for tanks in Pt 4, Ch 6,7.

2.7 Deckhouses and modules

2.7.1 The scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9. Where deckhouses support equipment loads, they are to be suitably reinforced.

2.7.2 The strength of containerised modules, which do not form part of the main hull structure, will be specially considered in association with the design loadings.

2.7.3 When containerised modules can be subjected to wave loading, the scantlings are not to be less than required by 2.7.1.

2.8 Pipe racks

2.8.1 The pipe rack is to be designed for the following normal operating loads as applicable:

- Gravity loads.
- Maximum dynamic loads due to wave induced unit motions.
- Direct wind loads.
- Ice and snow loads.
- Hull flexure due to hull girder bending

2.8.2 The pipe rack supports are also to be designed for an emergency condition, as defined in Ch 8,1.4.

2.8.3 In general, the pipe rack supports are to be aligned with the primary under-deck structure. Where this is not practicable, additional under-deck supports are to be fitted. Deck girders and under-deck supports are to comply with Pt 4, Ch 6,4.

2.8.4 In the emergency condition, arrangements are to be made to restrain the pipes in their stowed position and details are to be submitted for approval.

2.9 Bulk storage vessels

2.9.1 Free-standing bulk storage vessels are to comply with the requirements of Ch 8,4.

2.9.2 The deck supports under free-standing bulk storage vessels are to comply with the requirements for local structure in Pt 4, Ch 6 taking into account the maximum design reaction forces.

2.9.3 Where bulk storage vessels penetrate watertight decks and can be subjected to external hydrostatic pressure due to progressive flooding in hull damage conditions, the bulk storage vessel is to be suitably reinforced and the permissible stress is not to exceed the Code stress in accordance with Ch 8,4.

2.10 Watertight and weathertight integrity

2.10.1 The general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

2.10.2 The integrity of the weather deck is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise such items are to be enclosed in superstructures or deckhouses fully complying with the Rules. Full details are to be submitted for approval.

2.10.3 Where items of plant equipment or pipes penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval. Free flooding pipes, which penetrate shell boundaries, are to have a wall thickness not less than the adjacent shell plating.

2.10.4 Where bulk storage vessels penetrate watertight decks or flats, the arrangements to ensure watertight integrity will be specially considered, *see* 2.9.3.

2.11 Access arrangements and closing appliances

2.11.1 For requirements in respect of coamings and closing of deck openings, *see* Pt 4, Ch 7,6.

2.11.2 The access arrangements on ship units and other surface type units are to comply with 2.12. For other unit types, the general requirements of 2.12 are to be complied with, as applicable.

2.11.3 Ladders and platforms in tanks, pump-rooms, cofferdams, access trunks and void spaces are to be securely fastened to the structure.

2.12 Access to spaces in oil storage areas

2.12.1 Access arrangements to tanks for the storage of oil in bulk and adjacent spaces, including cofferdams, voids, vertical wing and double bottom ballast tanks, is to be direct from the open deck and such as to ensure their complete inspection.

2.12.2 In column-stabilised units where access from the open deck is not practicable, access to oil storage tanks and adjacent spaces is to be from trunks which are mechanically ventilated in accordance with Section 3. Every space is to be provided with a separate access without passing through adjacent spaces.

2.12.3 Access to double bottom tanks in way of oil storage tanks, where wing ballast tanks are omitted, is to be provided by trunks from the exposed deck led down the bulkhead. Alternative proposals will, however, be considered, provided the integrity of the inner bottom is maintained.

2.12.4 Access to double bottom spaces may also be through a cargo pump-room, pump-room, deep cofferdam, pipe tunnel or similar compartments, subject to consideration of ventilation aspects.

2.12.5 Where a duct keel or pipe tunnel is fitted, and access is normally required for operational purposes, access is to be provided at each end and at least one other location at approximately mid-length. Access is to be directly from the exposed deck. Where an after access is to be provided from the pump-room to the duct keel, the access manhole from the pump-room to the duct keel is to be provided with an oiltight cover plate. Mechanical ventilation is to be provided and such spaces are to be adequately ventilated prior to entry. A notice board is to be fitted at each entrance to the pipe tunnel stating that before any attempt is made to enter, the ventilating fan must have been in operation for an adequate period. In addition, the atmosphere in the tunnel is to be sampled by a reliable gas monitor, and where an inert gas system is fitted in cargo tanks, an oxygen monitor is to be provided.

2.12.6 Every double bottom space is to be provided with separate access without passing through other neighbouring double bottom spaces.

2.12.7 Where the tanks are of confined or cellular construction, two separate means of access from the weather deck are to be provided, one to be provided at either end of the tank space.

2.12.8 For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space. The minimum clear opening is to be not less than 600 mm x 600 mm.

2.12.9 Where practicable, at least one horizontal access opening of 600 mm x 800 mm clear opening is to be fitted in each horizontal girder in all spaces and weather deck to assist in rescue operations.

2.12.10 For access through vertical openings, or manholes providing passage through the length and breadth of the space, the minimum clear opening is to be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom shell plating, unless gratings or other footholds are provided.

2.12.11 In double hull construction where the wing ballast tanks have restricted access through the vertical transverse webs, permanent arrangements are to be provided within the space to permit access for inspection at all heights in each bay. These arrangements, which should comprise fixed platforms, or other means, are to provide sufficiently close access to carry out Close-Up Surveys, as defined in Pt 1, Ch 3, using limited portable equipment where appropriate. Details of these arrangements are to be submitted for approval.

2.12.12 On units with very large oil storage tanks, it is recommended that consideration be given to providing permanent facilities for staging the interior of tanks situated within the oil storage region and of large tanks elsewhere. Suitable provisions would be:

- Staging which can be carried on board and utilised in any tank, including power-operated lift or platform systems.
- Enlargement of structural members to form permanent, safe platforms, e.g., bulkhead longitudinals widened to form stringers (in association with manholes through primary members).
- Provision of inspection/rest platforms at intervals down the length of access ladders.
- Provision of manholes in upper deck for access to staging in cargo tanks.

2.13 Access hatchways to oil storage tanks

2.13.1 The general requirements of Pt 4, Ch 7,6 are to be complied with.

2.14 Loading of hot oil in storage tanks

2.14.1 Hot oil may be loaded in oil storage tanks at the temperatures given below, without the need for temperature distribution and thermal stress calculations, provided the following temperatures are not exceeded during operations:

(a) 65°C for sea temperatures of 0°C and below;
(b) 75°C for sea temperatures of 5°C and above; and
(c) by linear interpolation between (a) and (b) above, for sea temperatures between 0°C and 5°C.

2.14.2 Where the stored oil is to be loaded or heated to higher temperatures than those specified in 2.14.1 before unloading, temperature distribution investigations and thermal stress calculations may be required. For ship units and other surface type units, *see* Pt 4, Ch 9,12 of the Rules for Ships.

2.15 Compartment minimum thickness

2.15.1 On semi-submersible units, within the oil storage tank region in oil storage units including wing ballast tanks and cofferdams at the ends of or between oil storage tanks, the thickness of primary member webs and face-plates, hull envelope and bulkhead plating is to be not less than 7,5 mm.

2.15.2 Pump-rooms and other adjacent compartments are also to comply with 2.15.1.

2.15.3 The minimum compartment thickness in deep draught caisson units and buoys will be specially considered but is not to be less than 7,5 mm.

2.15.4 The compartment minimum thickness is to comply with:

- Part 10 for ship units; and
- Pt 4, Ch 9,10 of the Rules for Ships for other surface type units.

■ *Section 3* Hazardous areas and ventilation

3.1 General

3.1.1 For the application of hazardous area classification and related ventilation requirements, *see* Pt 7, Ch 2.

3.1.2 Adequate ventilation is to be provided for all areas and enclosed compartments associated with the oil storage production and process plant. The capacities of the ventilation systems are to comply, where applicable, with the requirements of Pt 7, Ch 2,6, or to an acceptable Code or Standard adapted to suit the marine environment and taking into account any additional requirements which may be necessary during start-up of the plant.

3.1.3 Ventilation in the vicinity of mud tanks is to be specially considered to ensure adequate dilution of any dangerous gases.

3.1.4 For units using oil-based mud, the tanks are to be provided with special ventilation arrangements, and for open systems, the maximum oil density in the air above the tanks is not to exceed 5 mg/m^3. Ventilation of the enclosed spaces with open active mud tanks or pits is to be arranged for at least 30 air changes per hour for personnel comfort.

■ *Section 4* Pollution prevention

4.1 General

4.1.1 Sumps and savealls are to be provided at potential spillage points, and drainage systems are to have adequate capacity and be designed for ease of cleaning.

4.1.2 Production manifolds are to be located and installed so that in the event of leakage in an enclosed area, a leakage detection and shut-down system will be activated. In open areas, arrangements are to be such that oil spillage will be contained, and that suitable drainage and recovery provisions are made.

4.1.3 Maintenance of production and process systems and equipment is to be governed by a permit-to-work system with rigid control on spillage prevention when opening up or testing is being carried out.

4.1.4 The arrangements for the onboard storage, and the disposal, of bilge and effluent from the production and process plant areas and spaces are to be submitted for consideration.

4.1.5 Oily water treatment systems are to have sufficient capacity for treatment of bilge and effluent water from the production and process plant areas and spaces.

4.1.6 When oil is added to the drilling mud, provision is to be made to limit the spread of oil on the unit, and to prevent the discharge of oil and oily residue into the sea by the provision of de-oilers and suitably alarmed oil monitoring devices.

4.1.7 Drilling bell nipples, flow lines, ditches, shale shakers, mud rooms and mud tanks and pumps are to be designed for maximum volume throughput without spillage. Equipment requiring maintenance is to have adequate spillage catchment arrangements.

4.1.8 Pollution prevention arrangements are to be such that the unit can comply with the requirements of the relevant National Administrations in the country of registration and in the areas of operation as applicable.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to accommodation and offshore support units as defined in Pt 1, Ch 2,2 whose primary function is to provide support services to offshore installations. Self-elevating accommodation units which are unmanned in transit conditions need not comply with Section 3.

1.1.2 The requirements in this Chapter are supplementary to those given in the relevant Parts of the Rules.

1.1.3 The requirements for fire-fighting units are given in Chapter 5.

1.1.4 Support vessels which have a diving complex on board are to have the diving installation approved in accordance with LR's *Rules and Regulations for the Construction and Classification of Submersibles and Underwater Systems* or an acceptable standard.

1.1.5 When accommodation units are to operate for prolonged periods adjacent to live offshore hydrocarbon exploration or production installations, it is the responsibility of the Owner/Operator to comply with the relevant regulations of the National Administrations in the country of registration and/or the area of operation, as applicable. Special consideration will be given to the safety requirements for classification purposes, *see* Pt 1, Ch 2.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Class notations for fire-fighting units are to be in accordance with Chapter 5.

1.2.3 In general, units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class type notations, as appropriate:

- Accommodation unit.
- Crane unit.
- Diving support unit.
- Support unit.
- Multi-purpose support unit.
- Pipe laying unit.

1.2.4 Units engaged in more than one function may be assigned a combination of class type notations at the discretion of the Classification Committee.

1.2.5 Support units engaged in more than two functions may be assigned the type notation multi-purpose support unit.

1.2.6 Lifting appliances are to comply with LR's *Code for Lifting Appliances in a Marine Environment*, *see also* Chapter 11.

1.2.7 When the type notation Crane unit is assigned to a unit, the main deck lifting appliances on the unit are considered to form an essential feature and therefore are to be included in the class.

1.2.8 Where the lifting appliances form an essential feature of a classed unit, the special feature class notation **LA** will be assigned, *see* Chapter 11.

1.2.9 Other special features class notations associated with lifting appliances may be assigned, *see* Chapter 11.

1.3 Scope

1.3.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- Strength of structure for accommodation.
- Supports for accommodation modules.
- Structure in way of diving installations.
- Structure in way of cranes.
- Structure in way of pipe laying equipment.
- Bilge systems and cross-flooding arrangements on accommodation units.
- Electrical installations on accommodation units.

1.4 Installation layout and safety

1.4.1 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas.

1.4.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.4.3 Additional requirements for safety and communication systems are given in Part 7.

1.5 Plans and data submission

1.5.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

Section 2
Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by Ch 1,2 and Pt 4, Ch 1,4, the following additional plans and information are to be submitted as applicable:

- Structural plans of the accommodation including deckhouses and modules.
- Design calculations for containerised modules.
- Module support frames or skids and details of attachments.
- Structural arrangements and supports under diving installations.
- Structural arrangements in way of crane supports.
- Structural arrangements and supports under pipe laying equipment.

2.2 General

2.2.1 The general hull strength is to comply with the requirements of Part 4, taking into account the applied weights and forces due to the accommodation, diving installations, pipe laying equipment and cranes, and the local structure is to be suitably reinforced. Attention should be paid to loads resulting from hull flexural effects at support points.

2.2.2 The scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9.

2.2.3 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.2.4 When containerised modules can be subjected to wave loading or protect openings leading into buoyant spaces, the scantlings are not to be less than required by 2.2.2.

2.2.5 The structural strength of the connections between containerised modules and the supporting frame or structure are to comply with the general strength requirements of Pt 4, Ch 6,9, taking into account the unit's motions and marine environmental aspects.

2.2.6 The connections of containerised modules are also to satisfy an emergency static condition with an applied horizontal force F_H in any direction as follows:

$F_H = W \sin\theta$ N (tonne-f)

where

θ = 25° for semi-submersible units
θ = 17° for self-elevating units
W = weight of the modules supported in N (tonne-f).

2.2.7 In the emergency static condition defined in 2.2.6 the permissible stress levels are to be in accordance with Pt 4, Ch 5,2.1.1(c).

2.3 Watertight and weathertight integrity

2.3.1 The general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

Section 3
Bilge systems and cross-flooding arrangements for accommodation units

3.1 Application

3.1.1 The requirements of this Section are only applicable to units with accommodation for more than 12 persons who are not crew members. For self-elevating units, *see also* 1.1.1.

3.2 Location of bilge main and pumps

3.2.1 The general requirements of Pt 5, Ch 12 and Ch 13 are to be complied with as applicable unless otherwise specified in this Section.

3.2.2 The bilge main is to be arranged so that no part is situated nearer to the side of the unit than the damage penetration zone.

3.2.3 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the damage penetration zone, a non-return valve is to be fitted at the pipe connection junction with the bilge main.

3.2.4 The emergency bilge pump and its connections to the bilge main are to be situated inboard of the damage penetration zone.

3.2.5 At least three power bilge pumps are to be provided. Where practicable, these pumps are to be placed in separate watertight compartments which will not be readily flooded by the same damage. In units where engines and auxiliary machinery are located in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments.

3.2.6 The bilge pumping units are to be such that at least one power pump will be available in all circumstances in which the unit may be flooded after damage. This requirement will be satisfied if:

(a) one of the pumps is an emergency pump of the submersible type having a source of power situated above the bulkhead deck or maximum anticipated damage load line; or

(b) the pumps and their power sources are located throughout the length of the unit so that, under any conditions of flooding that the unit is required to withstand by Statutory Regulation, at least one pump in an unaffected compartment will be available.

3.3 Arrangement and control of bilge system valves

3.3.1 The valves and distribution boxes associated with the bilge pumping system are to be arranged to enable any one of the bilge pumps to pump out any compartment in the event of flooding. All the necessary valves for controlling the bilge suctions are to be capable of being operated from above the bulkhead deck or maximum anticipated damage load line. The controls for these valves are to be clearly marked and a means provided at their place of operation to indicate clearly whether they are open or closed.

3.3.2 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of pumping out any compartment under flooding conditions. In this case, only the valves necessary for the operation of this emergency system need to be operable from above the bulkhead deck or maximum anticipated damage load line.

3.4 Prevention of communication between compartments in the event of damage

3.4.1 Provision is to be made to prevent any compartment served by a bilge suction pipe being flooded in the event of the pipe being damaged by collision or grounding in any other compartment. For this purpose, where any part of the pipe is situated outboard of the damage penetration zone, or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

3.5 Cross-flooding arrangements

3.5.1 Cross-flooding arrangements are not permitted as a means of attaining the damage stability criteria in accordance with Pt 4, Ch 7.

3.5.2 Cross-flooding arrangements may be used under control to restore a situation after damage. Such arrangements are not to be automatic or self-acting. Controls are to be situated above the worst anticipated damage waterline.

■ *Section 4*
Additional requirements for the electrical installation

4.1 General

4.1.1 In general, electrical installations are to comply with the requirements of Pt 6, Ch 2.

4.1.2 The requirements of this Section are applicable to units with accommodation for more than 50 persons, who are not crew members.

4.2 Emergency source of electrical power

4.2.1 A self-contained emergency source of electrical power is to be provided.

4.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, where fitted on surface type units.

4.2.3 The location of the emergency source of electrical power and associated transforming equipment, if any, the transitional source of emergency power, the emergency switchboard and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard is to be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A (*see* Pt 7, Ch 3) will not interfere with the supply, control and distribution of emergency electrical power. The space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard is not to be contiguous to the boundaries of machinery spaces of Category A, *see* Pt 7, Ch 3, and those spaces containing the main source of electrical power, associated transforming equipment, if any, or the main switchboard. Where this is not practicable, details of the proposed arrangements are to be submitted.

4.2.4 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits.

4.2.5 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of 36 hours, emergency lighting:
  (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars;
  (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
  (iii) in the machinery spaces and main generating stations including their control positions;
  (iv) in all control stations, machinery control rooms, and at each main and emergency switchboard;
  (v) at all stowage positions for fireman's outfits;
  (vi) at the steering gear;
  (vii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors;
  (viii) at every survival craft, muster and embarkation station;
  (ix) over the sides to illuminate the area of water into which survival craft are to be launched;
  (x) on helicopter decks.

(b) For a period of 36 hours:
  (i) the navigation lights, other lights and sound signals required by the *International Regulations for the prevention of Collisions at Sea*, in force;
  (ii) the radio communications as required by Amendments to SOLAS 1974 chapter IV as applicable;
  (iii) the navigational aids as required by Amendments to SOLAS 1974 Regulation V/19 as applicable;
  (iv) general alarm and communication systems as required in an emergency;
  (v) intermittent operation of the daylight signalling lamp and the unit's whistle;
  (vi) the fire and gas detection systems and their alarms;
  (vii) emergency fire pump; the automatic sprinkler pump, if any; and the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;
  (viii) one of the refrigerated liquid carbon dioxide units intended for fire protection, where both are electrically driven;
  (ix) on column-stabilised units; ballast valve control system, ballast valve position indicating system, draft level indicating system, tank level indicating system and the largest single ballast pump;
  (x) abandonment systems dependent on electric power.

(c) For a period of 24 hours:
  (i) permanently installed diving equipment necessary for the safe conduct of diving operations, if dependent upon the unit's electrical power;
  (ii) the capability of closing the blow out preventer and of disconnecting the unit from the wellhead arrangements, if electrically controlled, unless it has an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of 24 hours.

(d) The steering gear for the period of time required by Pt 5, Ch 19,6.

(e) For a period of four days, any signalling lights or sound signals which may be required for marking offshore structures.

(f) For a period of half an hour:
  (i) any watertight doors if electrically operated together with their control, indication and alarm circuits;
  (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The lift cars may be brought to deck level sequentially in an emergency.

4.2.6 The emergency source of electrical power may be either a generator or an accumulator battery, which are to comply with the following:

(a) Where the emergency source of electrical power is a generator, it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed-cup test) of not less than 43°C;
  (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 4.2.5 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
  (iii) provided with a transitional source of emergency electrical power according to 4.2.7.

(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
  (i) carrying the emergency electrical power without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 4.2.7.

4.2.7 The transitional source of emergency electrical power required by 4.2.6 is to consist of an accumulator battery suitably located for use in an emergency, which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the following services, if they depend upon an electrical source for their operation:

(a) For half an hour:
  (i) the lighting required by 4.2.5(a) and 4.2.5(b)(i);
  (ii) all services required by 4.2.5(b)(iii), (iv) and (v) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(b) Power to operate the watertight doors at least three times, (i.e., closed-open-closed), against an adverse list of 15°, but not necessarily all of them simultaneously, together with their control, indication and alarm circuits as required by 4.2.5(f)(i).

4.2.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

4.2.9 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

4.2.10 No accumulator battery except for engine starting, fitted in accordance with this Section, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged.

4.2.11 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

4.2.12 In order to ensure ready availability of the emergency source of electrical power, arrangements are to be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power will be available to the emergency circuits.

4.2.13 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter apply to mobile offshore units intended for fire-fighting operations and are additional to those applicable in other Parts of the Rules.

1.1.2 A unit provided with fire protection and fire-fighting equipment in accordance with these Rules will be eligible for an appropriate class notation.

1.1.3 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration within whose territorial jurisdiction the fire-fighting unit is intended to operate.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Units complying with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of one of the following class notations as applicable:

Fire-fighting unit 1 (total monitor discharge capacity in brackets).
Fire-fighting unit 2 (total monitor discharge capacity in brackets).
Fire-fighting unit 3 (total monitor discharge capacity in brackets).
Fire-fighting unit 1 (total monitor discharge capacity in brackets) with water spray.
Fire-fighting unit 2 (total monitor discharge capacity in brackets) with water spray.
Fire-fighting unit 3 (total monitor discharge capacity in brackets) with water spray.

1.2.3 The notation **Fire-fighting unit 1** or **Fire-fighting unit 2** or **Fire-fighting unit 3** signifies that a unit complies with these Rules and is provided with the appropriate fire-fighting equipment described in Table 5.1.1, with the total discharge capacity of monitors in m^3/h shown in brackets.

Table 5.1.1 Fire-fighting equipment

Equipment	Fire-fighting unit 1	Fire-fighting unit 2	Fire-fighting unit 3
Minimum total pump capacity, m^3/h	2400	7200	10 000
Minimum number of water monitors	2	3	4
Minimum discharge rate per monitor, m^3/h	1200	1800	1800
Minimum height of trajectory of jets of monitors above sea level, metres	45	70	70
Minimum range of monitor jets, metres	120	150	150
Minimum fuel capacity for monitors, hours	24	96	96
Number of hose connections each side of unit	4	8	8
Number of fireman's outfits	4	8	8

1.2.4 The addition of the words **with water spray** to the notations referred to in 1.2.3 signifies that a unit is provided with a water spray system which will provide an effective cooling spray of water over the vertical surfaces of the unit to enable it to approach a burning installation for fire-fighting purposes. The requirements for such a system are set out in Section 4.

1.2.5 Support units may be assigned additional class type notations when appropriate, *see* Ch 4,1.2.

1.3 Surveys

1.3.1 The requirements for surveys are given in Pt 7, Ch 3,1.3 of the Rules for Ships, which are to be complied with where applicable.

1.4 Plans and data submission

1.4.1 The requirements for submission of plans are given in Pt 7, Ch 3,1.4 of the Rules for Ships, which are to be complied with where applicable.

1.5 Definitions

1.5.1 The requirements for definitions are given in Pt 7, Ch 3,1.5 of the Rules for Ships, which are to be complied with where applicable.

Section 2
Construction

2.1 General

2.1.1 The requirements for construction are given in Pt 7, Ch 3,2 of the Rules for Ships, which are to be complied with where applicable.

Section 3
Fire-extinguishing

3.1 General

3.1.1 The requirements for fire-extinguishing are given in Pt 7, Ch 3,3 of the Rules for Ships, which are to be complied with where applicable.

Section 4
Fire protection

4.1 General

4.1.1 The requirements for fire protection are given in Pt 7, Ch 3,4 of the Rules for Ships, which are to be complied with where applicable.

Section 5
Lighting

5.1 General

5.1.1 The requirements for lighting are given in Pt 7, Ch 3,5 of the Rules for Ships, which are to be complied with where applicable.

Section

Section 1 Scope

1.1 General

1.1.1 The following requirements are for units intended for operations in ice and cold conditions.

1.1.2 Guidance on the appropriate requirements and notations is provided in Table 6.1.1.

Table 6.1.1 Ice and cold operations

Reference			Conditions	Description	Notation
Ice Operations					
Rules for Ships, Pt 8, Ch 2	Section 1		Application		
	Section 2 Section 3	Hull Machinery	General requirements	Applicable to all ice classes	
	Section 4	Hull	Light and very light ice conditions	For ships with length less than 150 m	**Ice Class 1E**
	Section 5	Machinery		Hull strengthening in forward region only	**Ice Class 1D**
	Section 6 Section 7	Hull Machinery	First-year ice conditions	*Finnish-Swedish Ice Class Rules*	**Ice Class 1C FS** **Ice Class 1B FS** **Ice Class 1A FS** **Ice Class 1AS FS**
	Section 8 Section 9	Hull Machinery		*Finnish-Swedish Ice Class Rules* with enhanced engine power for icebreaking capability	**Ice Class 1C FS(+)** **Ice Class 1B FS(+)** **Ice Class 1A FS(+)** **Ice Class 1AS FS(+)**
	Section 10 Section 11	Hull Machinery	Multi-year ice conditions	IACS Polar Ship Rules	**Ice Class PC7** **Ice Class PC6** **Ice Class PC5** **Ice Class PC4** **Ice Class PC3** **Ice Class PC2** **Ice Class PC1**
Cold Operations					
Provisional Rules for the Winterisation of Ships	Section 1		Application		
	Section 2	Hull materials	Low temperature operations	Hull construction materials	**Winterisation H(*t*)**
	Section 3	Equipment and systems	Low temperature operations	Short duration Seasonal duration Prolonged duration	**Winterisation C(*t*)** **Winterisation B(*t*)** **Winterisation A(*t*)**

Section 2
Ice environment

2.1 General

2.1.1 This Section is intended to give assistance on the selection of a suitable ice class notation for the operation of units in ice-covered regions.

2.1.2 The Owner is to confirm which notation is most suitable for their requirements. Ultimately, the responsibility rests with the Operator of the unit and their assessment of the ice and temperature conditions at the time.

2.1.3 The documentation supplied to the unit is to contain the ice class notation adopted, any operation limits for the unit and guidance on the type of ice that can be navigated for the nominated ice class.

2.2 Definitions

2.2.1 The World Meteorological Organisation's, WMO, definitions for sea ice thickness are given in Table 6.2.1.

Table 6.2.1 WMO definition of ice conditions

Ice conditions	Ice thickness
Medium first-year	1,2 m
Thin first-year, second stage	0,7 m
Thin first-year, first stage	0,5 m
Grey-white	0,3 m
Grey	0,15 m

2.2.2 Table 6.2.2 defines the ice classes in relation to the Rules and the equivalent internationally recognised Standards.

Table 6.2.2 Comparison of ice standards

Lloyd's Register class notation	Finnish-Swedish Ice Class	Canadian type
Ice Class 1AS FS(+) **Ice Class IAS FS**	IA Super	A
Ice Class 1A FS(+) **Ice Class 1A FS**	IA	B
Ice Class 1B FS(+) **Ice Class 1B FS**	IB	C
Ice Class 1C FS(+) **Ice Class 1C FS**	IC	D
Ice Class 1D	—	D
Ice Class 1E	—	E

2.3 Application

2.3.1 The variable nature of ice conditions is such that the average limits of the conditions are not easily defined. However, it is possible to plot the probable limits of the ice floes and the ice edge for each season. *See* Figs. 6.2.1 to 6.2.4 and Table 6.2.3.

2.3.2 Operation with **Ice Class 1C FS** may be possible up to 150 nm inside the 7/10 region shown depending on the severity of the winter. Operation with **Ice Class 1A FS** may be possible up to 150 nm inside the medium first-year ice shown depending on the severity of the winter. Operation up to the multi-year ice is possible most years with **Ice Class 1AS FS**.

2.3.3 Operation in the region between 7/10 and 1/10 in the ice-covered regions is possible with due care for units with no ice class. For units operating for extended periods in these areas, it will be necessary to specify and design for a minimum temperature for the hull materials. To cover all situations for non-ice class units, the material requirements of *The Provisional Rules for the Winterisation of Ships* are recommended.

2.4 Ice Class notations

2.4.1 Where the requirements of Pt 8, Ch 2 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) are complied with, the unit will be eligible for a special features notation, *see also* Table 6.1.1.

2.5 National Authority requirements

2.5.1 Certain areas of operation may require compliance or demonstration of equivalence with National Authority requirements. Table 6.2.2 gives the equivalence of National Authority requirements.

2.5.2 The standards of ice strengthening required by the Rules have been accepted by the Finnish and Swedish Boards of Navigation as being such as to warrant assignment of the Ice Classes given in Table 6.2.2.

2.5.3 Units intending to navigate in the Canadian Arctic must comply with the Canadian Arctic Shipping Pollution Prevention Regulations established by the Consolidated Regulations of Canada, 1978, Chapter 353, in respect of which Lloyd's Register is authorised to issue Arctic Pollution Prevention Certificates.

2.5.4 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary ice class notation required to permit operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

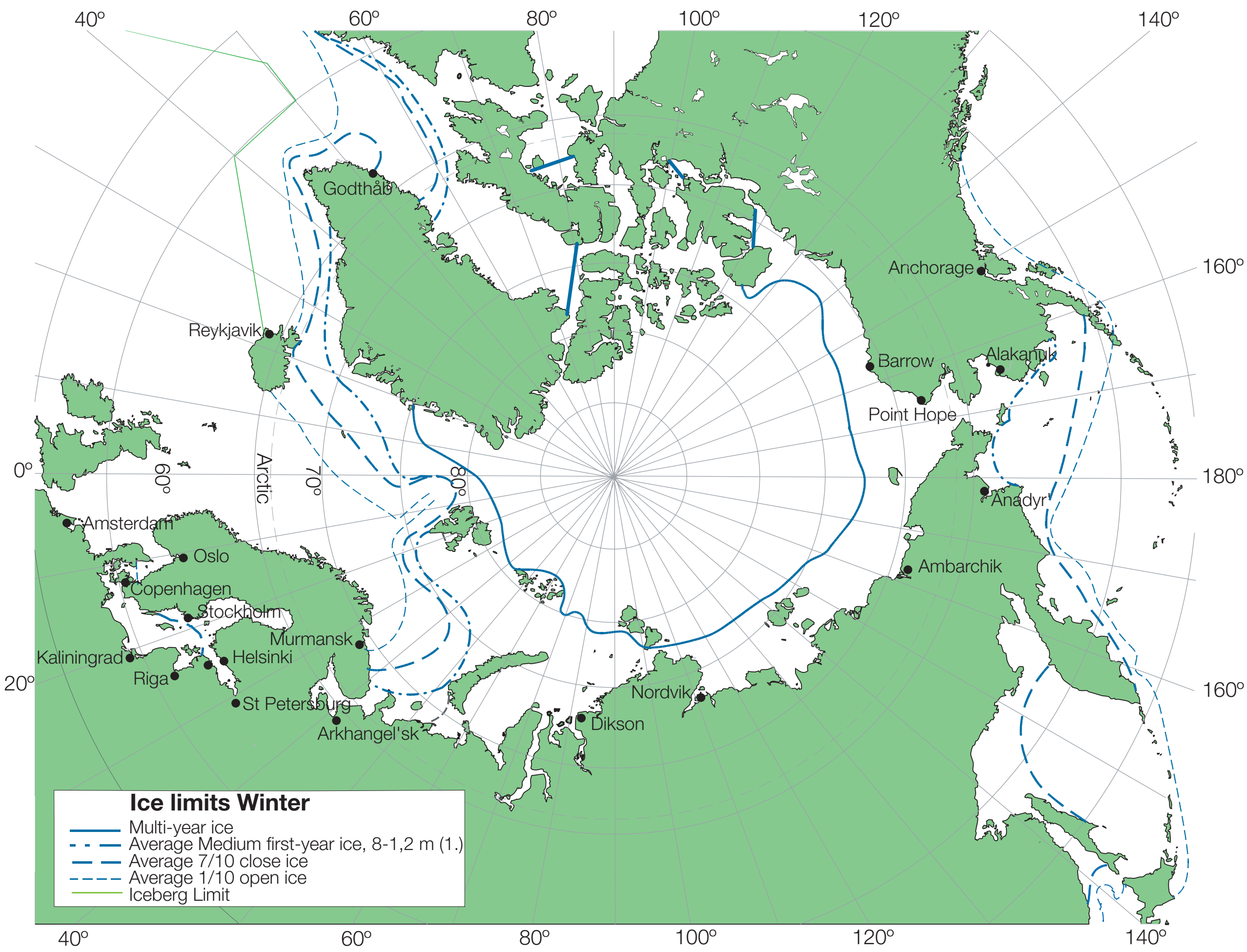


Fig. 6.2.1 Ice Limits for the Arctic Winter

2.6 Ice conditions

2.6.1 Charts and images for the current and recent ice conditions in all areas of the world plus information on icebergs can be found from the National Ice Centre on the worldwide web at: www.natice.noaa.gov.

2.6.2 Daily ice information and consultation is available from the Canadian ice service which is part of the Canadian department of the environment. Their website can be found at: www.ice-glaces.ec.gc.ca.

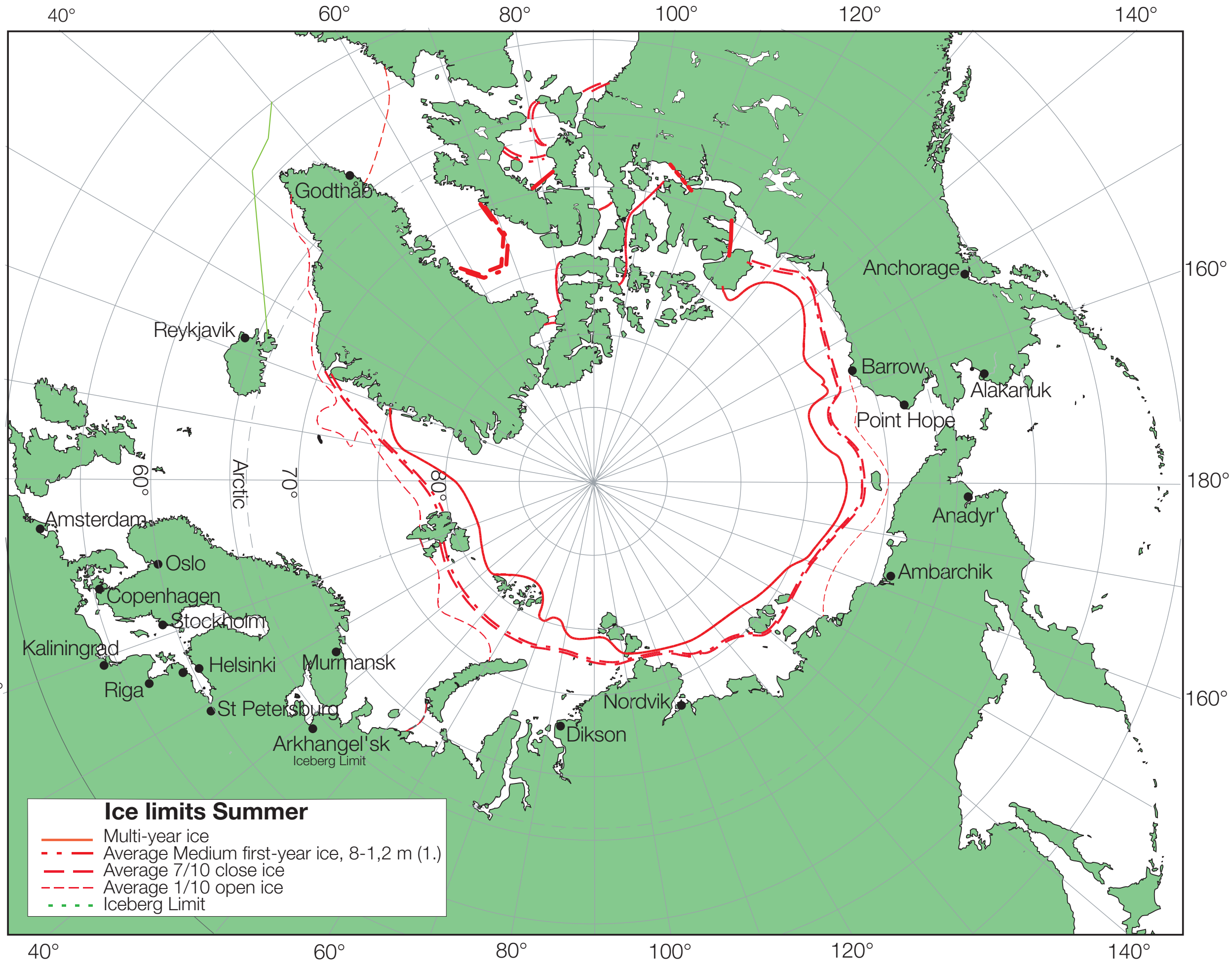


Fig. 6.2.2 Ice Limits for the Arctic Summer

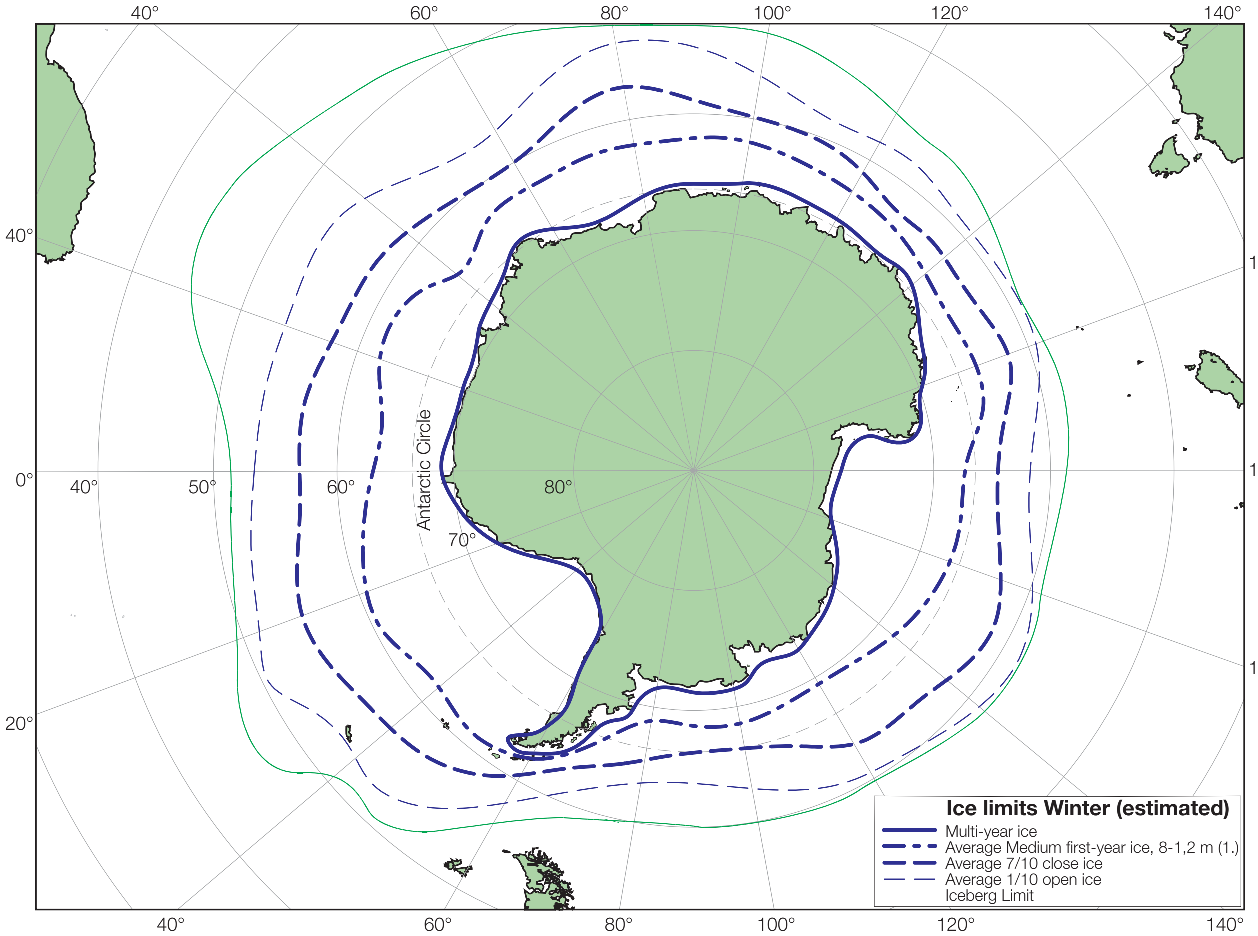


Fig. 6.2.3 Ice Limits for the Antarctic Winter

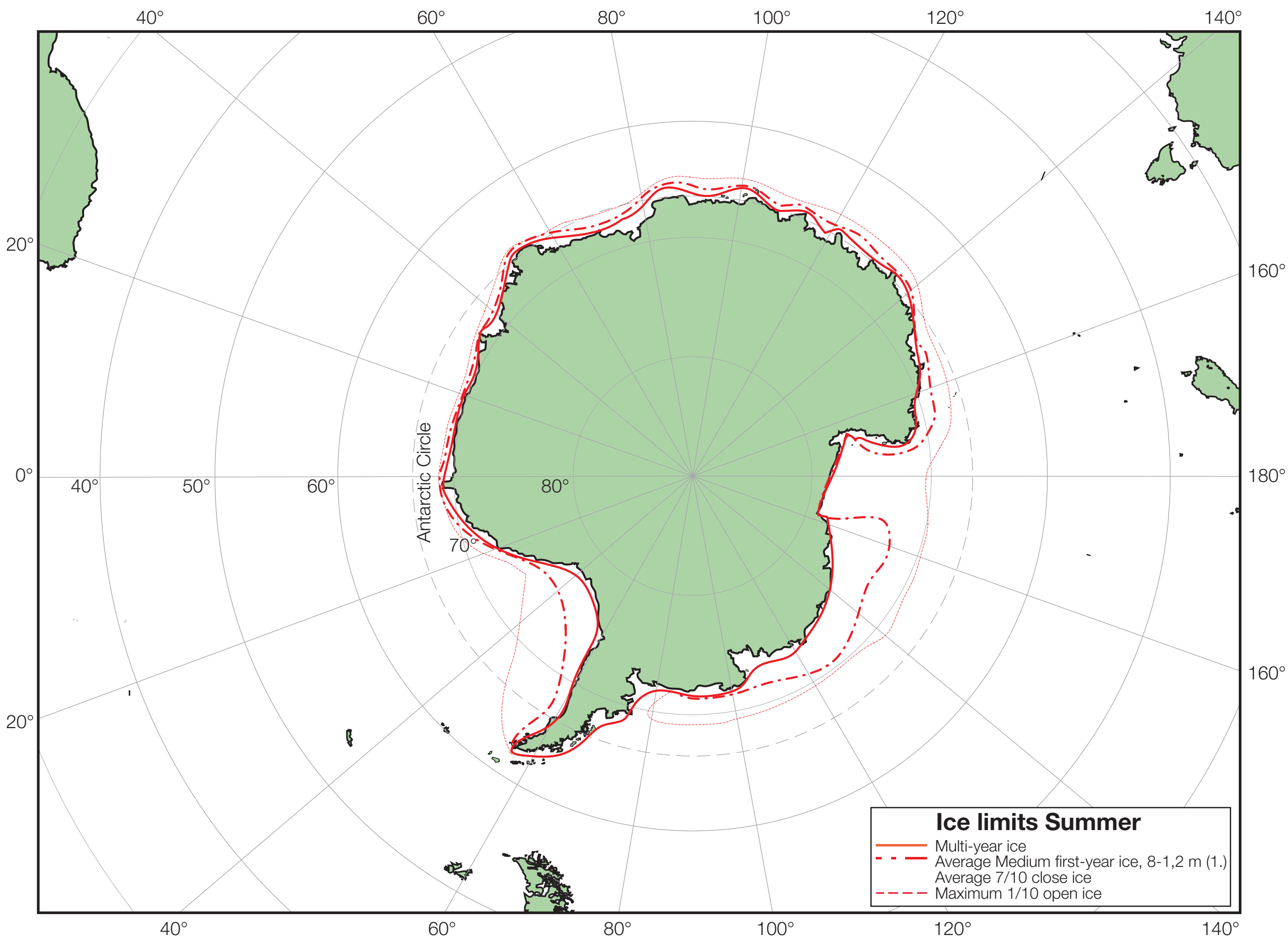
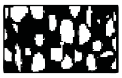
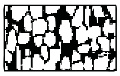
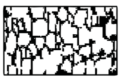
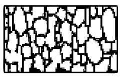
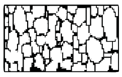


Fig. 6.2.4 Ice Limits for the Antarctic Summer

Table 6.2.3 Concentration of ice

Free ice		0/10				
Open water		< 1/10				
Very open drift		1/10		2/10		3/10
Open drift		4/10		5/10		6/10
Close pack/drift		7/10		8/10		
Very close pack		9/10		9+/10		
Compact/consolidated ice		10/10				

Section 3
Air environment

3.1 Air temperature

3.1.1 For units intended to operate in cold regions, the temperature on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships.*

3.1.2 The average external design air temperature is to be taken as the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years
Average = average during one day and one night
Lowest = lowest during the year
MDHT = Mean Daily High Temperature
MDAT = Mean Daily Average Temperature
MDLT = Mean Daily Low Temperature

Fig. 6.3.1 shows the definition graphically.

3.1.3 The lowest external design air temperature is to be taken as the lowest mean daily lowest air temperature in the area of operation. Where reliable environmental records for contemplated operational areas exist, the lowest external design air temperature may be obtained after the exclusion of all recorded values having a probability of occurrence of less than 3 per cent.

3.1.4 Lowest mean daily average air temperatures for the Arctic and Antarctic are provided in Figs. 6.3.2 to 6.3.3.

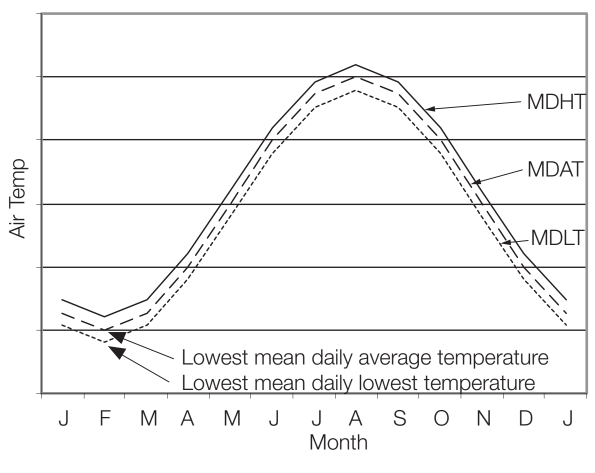


Fig. 6.3.1 Air temperature

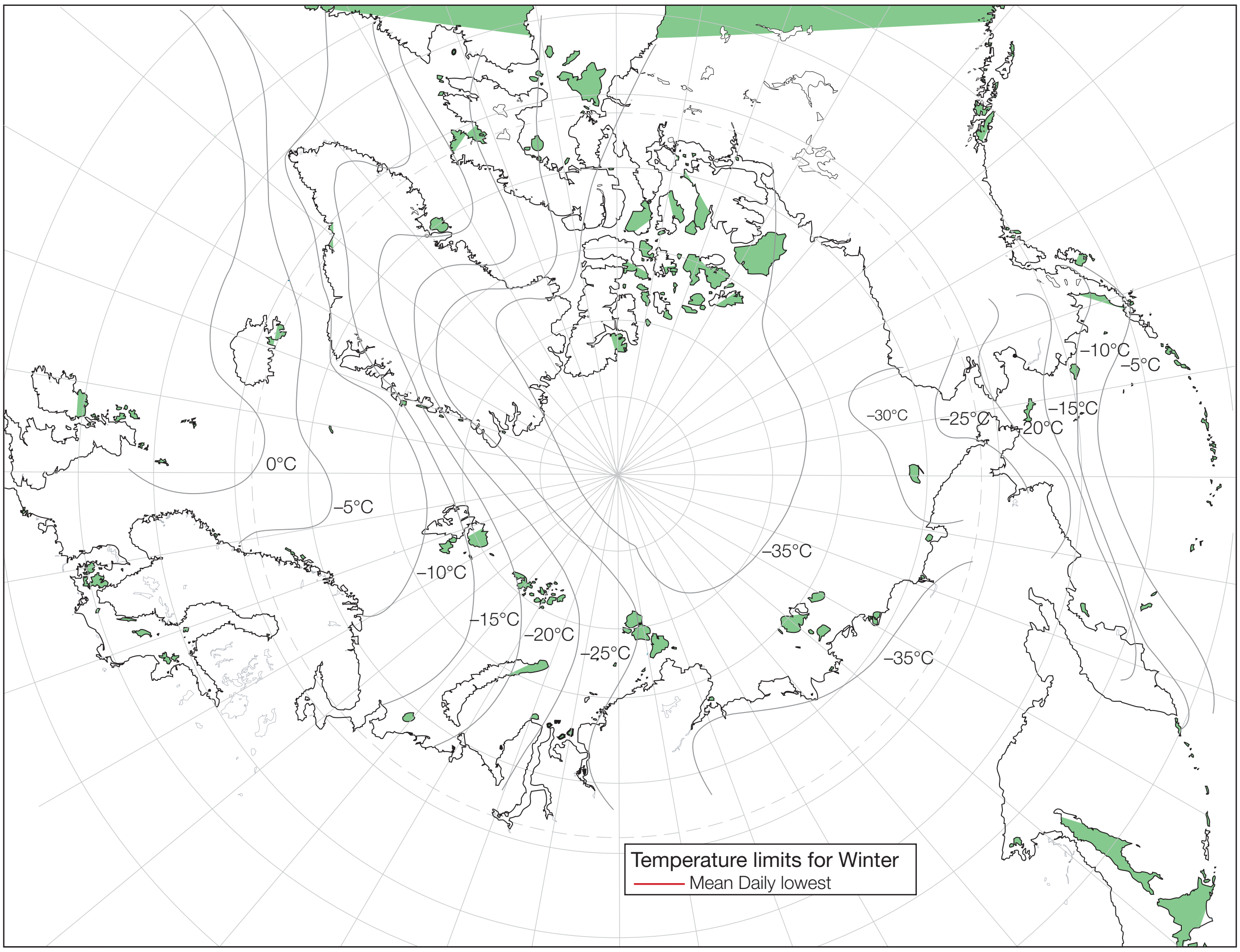


Fig. 6.3.2 Lowest mean daily average air temperatures for the Arctic

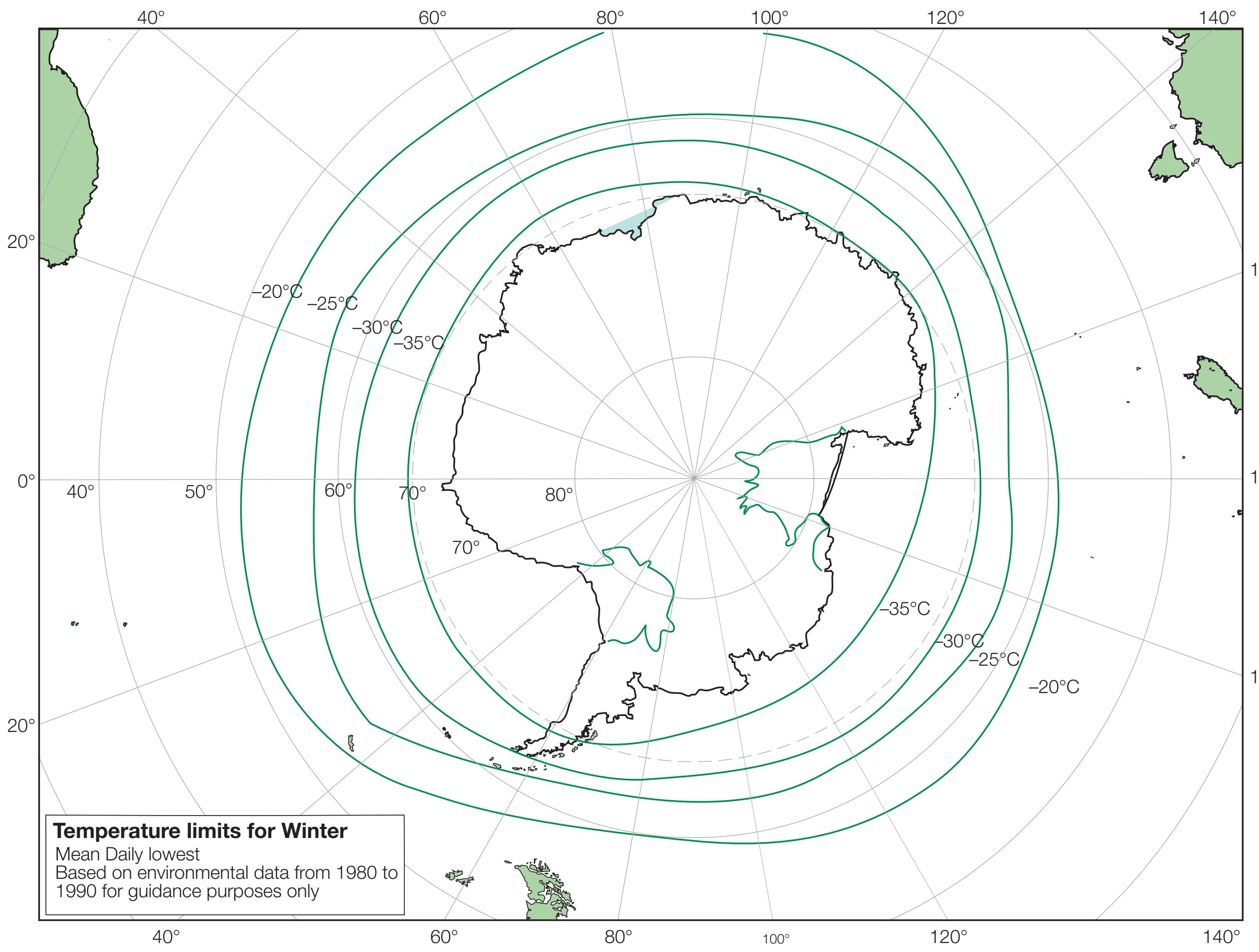


Fig. 6.3.3 Lowest mean daily average air temperatures for the Antarctic

■ *Section 4*
Icing Environment

4.1 Ice accretion

4.1.1 For units intended to operate in cold regions, the build-up of ice on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

4.1.2 Icing is to be considered for units operating in the following areas, *see* Figs. 6.4.1 and 6.4.2.

- The area north of latitude 65°30’N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30’N, longitude 15°E, north of latitude 73°30’N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea.
- The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W.
- All sea areas north of the North American continent west of the areas defined in sub-paragraphs above.
- The Bering and Okhotsk Seas and the Tartary Strait during the icing season.
- South of latitude 60°S.

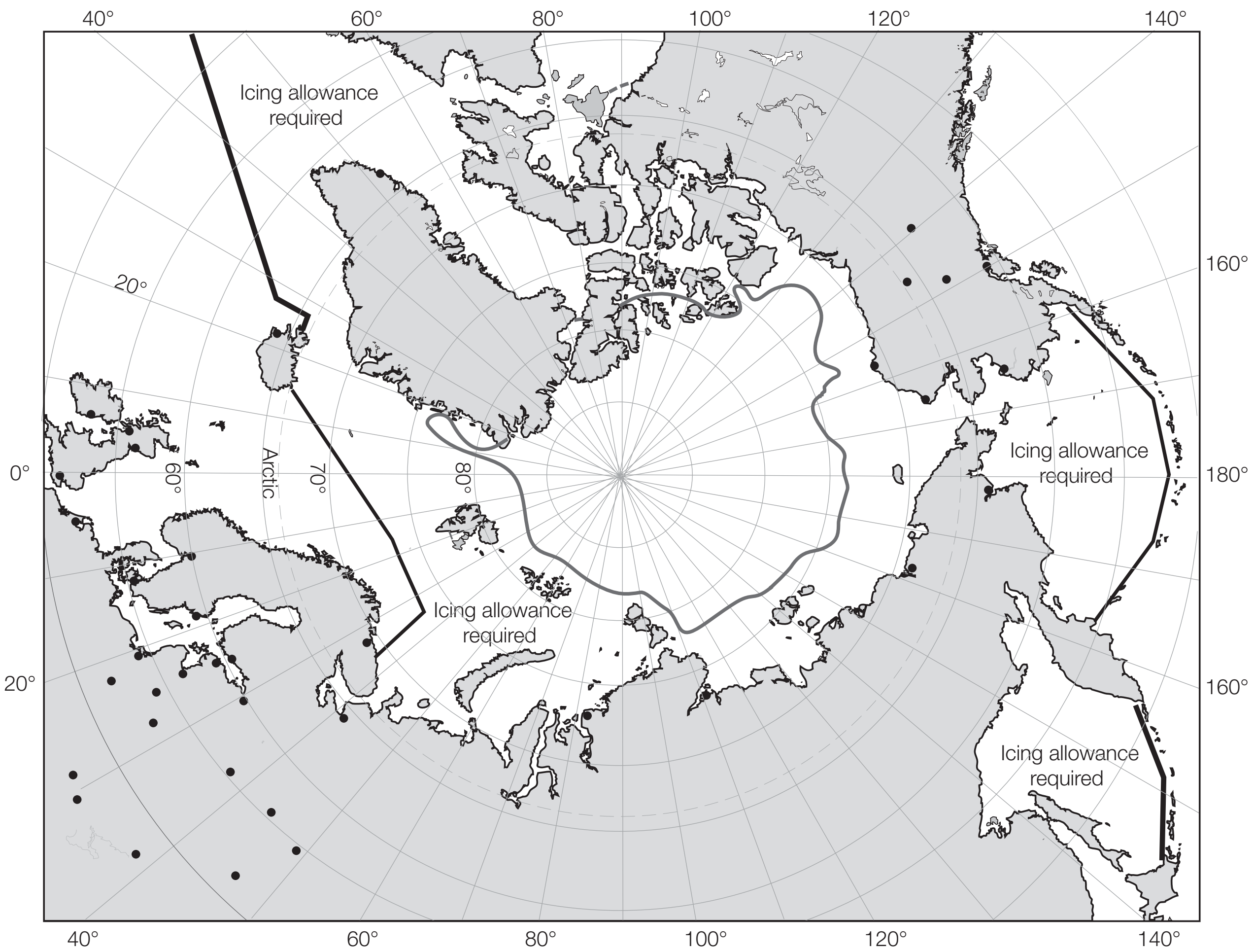


Fig. 6.4.1 Ice accretion limits for the Arctic

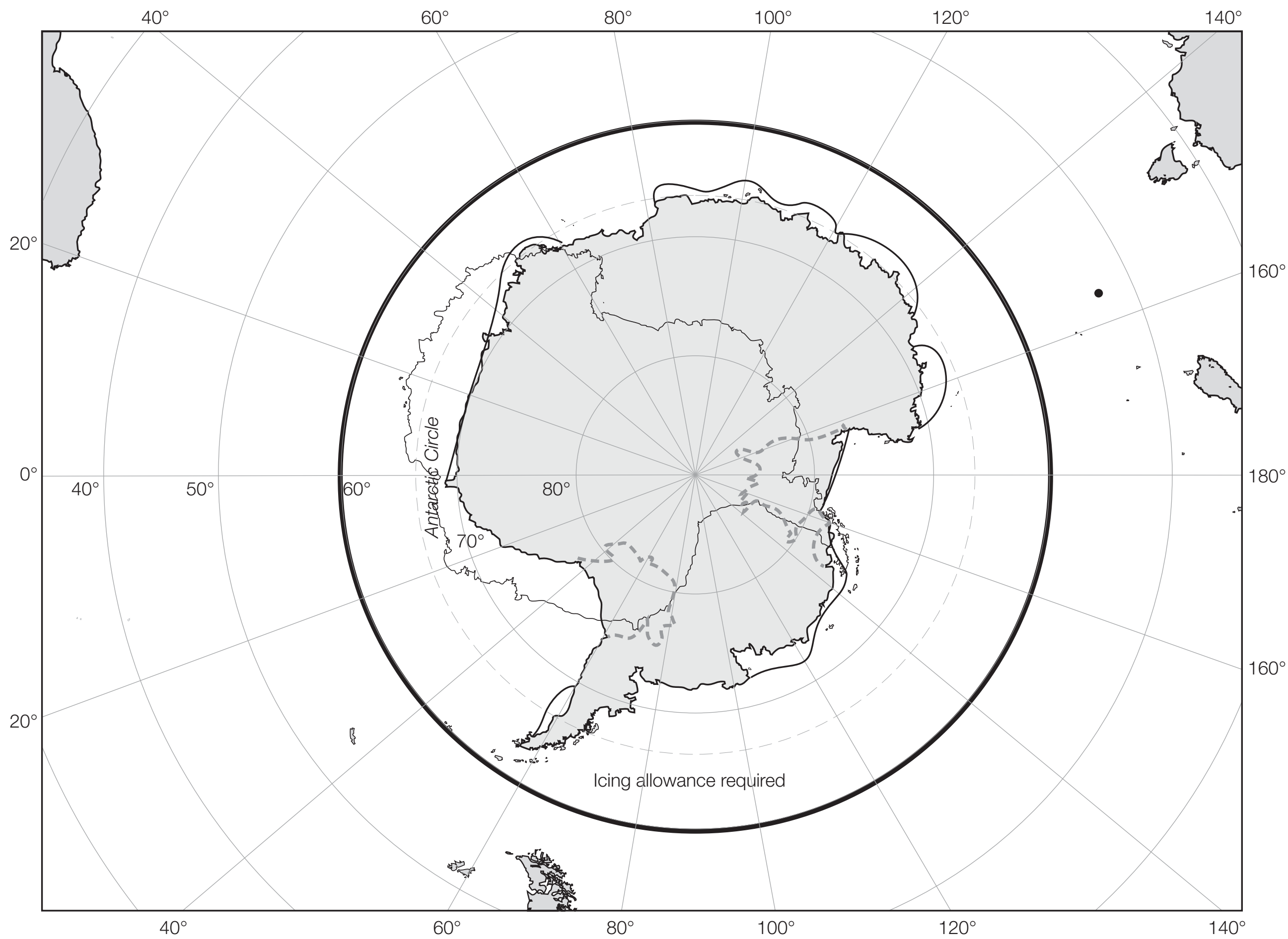


Fig. 6.4.2 Ice accretion limits for the Antarctic

■ *Section 5* Strengthening standard for navigation in ice – Application of requirements

5.1 Additional strengthening

5.1.1 When disconnectable units are required to navigate in ice and additional strengthening is fitted in accordance with the requirements given in this Chapter, an appropriate special features notation will be assigned. It is the responsibility of the Owners to determine which notation is most suitable for their requirements.

5.1.2 For semi-submersible units with twin lower hulls the ice strengthening, as required by this Chapter, is to be carried out to both hulls. Where the exposed deck of the lower hulls is situated below the upper limit of the ice belt, the strengthening of the deck will be subject to special consideration and the deck thickness is not to be less than the shell plating in the main ice belt.

5.1.3 The extent of reinforcement on units of unconventional form will be specially considered.

5.2 Plans and data submission

5.2.1 Plans, calculations and data are to be submitted as required by the relevant Parts of these Rules together with the additional information required by Part 8 of the Rules for Ships.

■ *Section 6* Strengthening requirements for navigation in ice

6.1 General

6.1.1 The strengthening requirements for navigation in ice are given in Pt 8, Ch 2 of the Rules for Ships which are to be complied with where applicable.

6.1.2 The requirements for strengthening for navigation in ice as given in Pt 8, Ch 2 of the Rules for Ships are intended for ships of conventional designs and arrangements. Units considered outside this applicability will be specially considered by LR and may require additional strengthening and structural analysis for the primary structure by direct calculation, or experimental verification. *See also* limits to the ship length and hull form contained in the engine power requirement in the *Finnish-Swedish Ice Class Rules* and icebreaking bow form for the *Polar Ship Rules*.

6.1.3 The requirements for strengthening for navigation in ice as given in Pt 8, Ch 2 of the Rules for Ships are intended for ships operating in typical ice voyages and harbour operations. The operation of units may require a rational analysis for determining the maximum operating ice pressures on the structure based on acceptable environmental data such as the design ice conditions, e.g., multi-year ice floe size and concentration, or whether assistance from icebreakers is anticipated.

6.1.4 When a unit operates in areas where there is the possibility of collision with icebergs, appropriate data is to be submitted and the structure suitably strengthened for the collision loads.

6.1.5 Special requirements will be required for sea inlet chests for machinery cooling and fire pump suctions and reference should be made to the relevant text of Pt 8, Ch 2 of the Rules for Ships. The design and arrangement of sea inlet chests will be specially considered as applicable to the type of unit.

■ *Section 7* Operation in ice conditions at a fixed location

7.1 General requirements

7.1.1 When a unit is required to operate at a fixed location in ice conditions, the designer/Builder is required to submit a rational analysis for determining the maximum operating ice pressures on the structure based on acceptable environmental data.

7.1.2 The minimum design temperature of the structure and steel grades will be specially considered, *see also* Pt 4, Ch 2.

7.1.3 The extent of additional strengthening will be specially considered by LR and additional structural calculations for the primary structure will be required.

7.1.4 When a unit operates in areas where there is the possibility of collision with icebergs, appropriate data is to be submitted and the structure suitably strengthened for the collision loads.

7.1.5 Special requirements will be required for sea inlet chests for machinery cooling and fire pump suctions and reference should be made to the relevant text of Pt 8, Ch 2 of the Rules for Ships. The design and arrangement of sea inlet chests will be specially considered as applicable to the type of unit.

7.1.6 When a unit has been reinforced and approved by LR for operating in ice, a suitable descriptive note will be included in the ClassDirect Live website.

■ *Section 8* Ice accretion and low temperatures

8.1 General requirements

8.1.1 For units intended to operate in cold regions, the build-up of ice on exposed surfaces is to be considered. *See The Provisional Rules for the Winterisation of Ships*.

8.1.2 When units are fitted with riser systems the arrangements are to be designed to minimise the effect of ice loadings on the risers.

8.1.3 Suitable steam generating equipment or an equivalent means is to be provided, with outlets and hoses, to keep designated areas free of ice and snow such that operation and inspection/maintenance may be conducted safely. Such equipment is to be capable of being used in at least the following locations:

- The working areas.
- The helicopter deck.
- Walkways and escape routes.
- Lifeboat embarkation station.

8.1.4 In the case of self-elevating units where the design of the elevating machinery is required to operate in ice conditions, suitable de-icing equipment is to be provided.

8.1.5 The starting requirements of the emergency generators for low temperature operation is to be in accordance with Pt 5, Ch 2,8.5 of the Rules for Ships.

8.1.6 Electrical equipment and cables likely to be exposed to sustained low temperatures are to be suitably constructed for the ambient conditions in accordance with a recognised National or International Standard.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the drilling plant, derricks and flare structures, etc., and drilling-related systems and equipment installed on board drilling units. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The Rules cover the approval of the drilling plant which includes the equipment and systems required for safe drilling operations but limited to those aspects defined in 1.3. The approval of the equipment includes all mechanical and structural components of the drilling plant covered by the Rules. The Rules also cover the protection of the environment with regard to pollution.

1.1.3 The operational aspects and reliability of the drilling plant are not covered by class except when they have an effect on the overall safety of the drilling unit, the personnel on board or the environment.

1.1.4 The Rules are framed on the understanding that units with an installed drilling plant facility will not be operated in environmental conditions more severe than those for the design basis and class approval. The drilling facilities are to be considered designed to operate under ambient conditions prevalent in the intended area of operation, and based on relevant MetOcean and climatic data.

1.1.5 It is the responsibility of the Owners/Operators to ensure that the drilling plant facility is properly maintained and operated by qualified personnel and that the test and operational procedures are clearly defined and complied with.

1.1.6 The limiting design criteria on which approval is based are to be stated in the unit's Operations Manual.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference is to be made.

1.2.2 Units fitted with an installed drilling plant facility which complies with the requirements of this Chapter, or recognised Codes and Standards agreed with LR, will be eligible for the assignment of the special features class notation **DRILL**.

1.2.3 When a unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional descriptive note may be assigned in accordance with Pt 1, Ch 2.

1.2.4 The latest issue of the following referenced standards is to be used unless otherwise agreed beforehand. Other recognised Standards may be used provided it can be shown that they meet or exceed the requirements of the referenced standards in Appendix A. When other codes or standards are proposed, gap analysis and risk assessments are to be provided by the dutyholder to demonstrate an equivalent level of safety to the recognised Standards in this notation.

1.3 Scope

1.3.1 Goal:

(a) The drilling plant is to be designed, constructed, installed and maintained satisfactorily for the intended service conditions in order to minimise the risk to the unit, personnel on board and to the environment. The drilling plant is to be operated and maintained by competent personnel.

(b) All drilling plants, regardless of design, are to comply with this goal. The prescriptive requirements in this Section are considered to provide a route to meeting this goal. Alternative arrangements which are considered by LR also to meet this goal will be accepted.

(c) Apart from other hazards noted elsewhere in these Rules, examples of some hazards specifically related to drilling operations are as follows:
- Blow out.
- Hydrogen sulphide and other toxic gases.
- Uncontrolled release of hydrocarbon gases.
- Loss of position.
- Fire or explosion.
- Loss of positive pressurisation in hazardous spaces or equipment.
- Ventilation in hazardous areas.
- Dropped objects.
- Failure of Zone management systems.
- Punch through (bottom supported units).
- Shallow gas (stability and fire risks).
- Radioactivity.
- Environmental spills.

Risk assessments are to be made by the dutyholder with regard to mitigating or limiting the effects of these and any other similar related hazards.

1.3.2 Any part, component or structure of the drilling system that is required to allow the rig to conduct drilling or well testing operations. This includes any outlet from hydrocarbon flares and vent systems, and includes the subsea blow out preventer stack, risers, conductors and any other subsea component that is required to allow drilling operations from the unit to be conducted but does not include subsea production equipment.

1.4 Plant design characteristics

1.4.1 The design and arrangement of the drilling plant, derricks and flare structures, etc., are to comply with the requirements of this Chapter and/or recognised Codes and Standards, *see* 1.5.

1.4.2 Attention is to be given to the relevant Statutory Regulations of the National Administrations in the country of registration and the area of operation, as applicable.

1.4.3 The plant and supporting structures above the deck are to be designed for all operating and transit conditions in accordance with recognised and agreed Codes and Standards, suitably modified to take into account the unit's motions and marine environmental aspects. Except for the emergency condition, as detailed in 1.4.4, the total stress in any component of the plant is not to exceed the Code value at the temperature concerned, unless expressly agreed otherwise by LR, whether the plant is operative or non-operative, when subjected to any of the following loads, as applicable:

- Static and dynamic loads due to wave-induced motions of the unit.
- Loads resulting from hull flexural effects at the plant support points, as appropriate.
- Direct wind loads.
- Normal gravity and functional loads.
- Thermal loads, as appropriate.
- Ice and snow loads, as appropriate.

1.4.4 In general, the plant and supporting structures above the deck are to be designed for an emergency static condition with the unit inclined to the following angle:

- Column-stabilised units:
  25° in any direction.
- Surface type units:
  22,5° heel, port and starboard, and trimmed to an angle of 10° beyond the maximum normal operating trim.
- Self-elevating units:
  17° in any direction in transit conditions only.

These angles may be modified by LR in particular cases as considered necessary. In no case is the inclined angle for the emergency static condition to be taken less than the maximum calculated angle in the worst damage condition in accordance with the appropriate damage stability criteria.

1.4.5 In the emergency condition defined in 1.4.4, the plant is to be assumed to have maximum operating weights, temperatures and pressures, unless agreed otherwise with LR. When applicable, the plant is also to be subjected to ice and snow loads. Wind loads need not be considered to be acting during this emergency condition. The total stress in any component of the plant or support structure above the deck is not to exceed the minimum yield stress of the material.

1.4.6 The permissible stresses in the primary hull structure below plant and equipment supports in transit, operating and emergency conditions are to be in accordance with Pt 4, Ch 5.

1.4.7 The design of the plant is to allow for adequate space and services for completion and intervention equipment, such as, but not limited to, wire line, logging, coiled tubing, snubbing, well completion, work over and well testing. The location is also to take into consideration the requirement for hazardous area classification of equipment and services. Communication and safety systems are also required to be considered in the design.

1.5 Recognised Codes and Standards

1.5.1 Installed drilling plant facilities designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner’s proposals at an early stage, in order that a basis for acceptance of the standards may be agreed. Refer to Appendix A for applicable international Codes and Standards considered by LR as an equivalent level of safety to Rule requirements.

1.5.2 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for the drilling plant structures and drilling related systems and equipment as defined in Appendix A. Other Codes and national Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.5.3 Where necessary, the Codes and Standards are to be suitably modified and/or adapted to take into account all marine environmental aspects.

1.5.4 The agreed Codes and Standards may be used for design, construction and installation but where considered applicable by LR, compliance with the additional requirements stated in the Rules is required. Where there is any conflict, the Rules will take precedence over the Codes or Standards.

1.5.5 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.6 Equipment categories

1.6.1 The approval and certification of drilling equipment is to be based on equipment categories agreed with LR.

1.6.2 Drilling equipment, including its associated pipes and valves, is to be divided into equipment categories **1A**, **1B** and **II**, depending on the complexity of manufacture and its importance with regard to the safety of personnel and the installation and the possible effect on the environment.

1.6.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in category **1A**.

II Equipment related to safety which is normally manufactured to recognised Codes and Standards and has proven reliability in service, but excludes equipment in category **1A** and **1B**.

1.6.4 A guide to equipment and categories is given in Appendix A. A full list of equipment categories for each drilling plant facility is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.7 Equipment certification

1.7.1 Drilling equipment is to be certified in accordance with the following requirements:

(a) Category **1A**
- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of a certificate of conformity.

(b) Category **1B**
- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of certificate of conformity.

(c) Category **II**
- Supplier's/manufacturer's works' certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.7.2 All equipment recognised as being of importance for the safety of personnel and the drilling plant installation is to be documented by a data book.

1.8 Fabrication records

1.8.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records are to include the following:
- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examination.
- Load, pressure and functional test reports.

1.9 Installation of drilling plant equipment

1.9.1 The installation of drilling equipment on board the unit is to be controlled by LR in accordance with the following principles:
- All Category **1A** and **1B** equipment delivered to the unit is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other necessary documentation.
- All Category II equipment delivered to the unit is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed production and process plant.
- Monitoring of functional tests after installation on board in accordance with an approved test programme.
- Issue of a plant installation report.

1.9.2 A test procedure, including acceptance criteria and functional description prior to the factory acceptance test of equipment, system or sub-system, is to be provided.

Mechanical completion to the satisfaction of LR is to be completed prior to starting or testing of any drilling equipment or system. The commissioning procedures are to contain all necessary information required to ensure safe start-up and shut-down of each equipment or system. All equipment and system operating and maintenance manuals are to be made available to LR before final commissioning.

The drilling package will undergo a final drilling trial before delivery, in accordance with Section 11. All drilling equipment and related systems will be required to operate simultaneously with simulated drilling loads and operate as close to the normal drilling operations design as possible. All drilling instrumentation and sensors will also be included in the trial. A guidance note on how to conduct final trials will be made available for the Owner.

1.10 Maintenance and repair

1.10.1 It is the responsibility of the Owners/Operators to ensure that installed drilling plant is maintained in a safe and efficient working condition in accordance with the manufacturer's specifications.

1.10.2 When it is necessary to repair or replace installed drilling plant, any repaired or spare part is to be subject to the equivalent certification as the original part.

1.10.3 The design and layout of the drilling systems are to provide safe working arrangements for operation and maintenance. Use of man-riding winches or baskets for routine maintenance should be discouraged.

1.10.4 Sufficient tools and test equipment to ensure safe and continued operation of the drilling plant are to be provided. Suitable tools and equipment for working at height and for use in hazardous areas are also to be provided.

1.11 Plans and data submissions

1.11.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules, together with the additional plans and information listed in this Chapter. Plans are to be submitted in triplicate, but only a single copy of supporting documents and calculations is required.

■ *Section 2* Structure

2.1 Plans and data submissions

2.1.1 The following additional plans and information are to be submitted:

- General arrangement plans of the drilling plant.
- Drilling derrick structural plans and design calculations.
- Raw water towers' structural plans and design calculations.
- Flares structures' structural plans and design calculations.
- Structural plans of equipment skids, support stools and design calculations.
- Structural plans of supports to lifting appliances.

2.2 Materials

2.2.1 Materials are to comply with Ch 1,4 and material grades are to comply with Pt 4, Ch 2 using the categories defined in this Section.

2.2.2 Support structures for the drilling plant are to be divided into the following categories:

- Primary structure.
- Secondary structure.

2.2.3 Main load-bearing members and elements subjected to high tensile or shear stresses are defined as primary structure. All other structure is considered to be secondary structure.

2.2.4 Some specific examples of structural elements which are considered as primary structure are as follows:

- Derrick legs and base plates.
- Derrick principal cross bearing.
- Derrick crown block/water table supports.
- Derrick bolts.
- Support stools (attached to the main/upper deck).
- Main legs, chords and end connections.
- Foundation bolts.

2.3 Supporting structure interfaces

2.3.1 The design loadings for all structures supporting plant, including equipment skids, support stools, tanks and storage vessels, are to be defined by the designers/Builders and calculations are to be submitted in accordance with an appropriate Code or Standard, *see* Appendix A.

2.3.2 The design of supporting structures for drilling facilities is to integrate with the primary hull under-deck structure.

2.3.3 The permissible stresses in the hull structure below the drilling plant are to be in accordance with Pt 4, Ch 5 and the local strength is to comply with Pt 4, Ch 6.

2.3.4 The BOP frame, lifting points or supports are to meet the requirements of API RP 2A-WSD.

2.4 Derrick and masts

2.4.1 The structural design of drilling derricks is to be in accordance with a recognised Code of Practice, such as API Spec 4F or acceptable equivalent, *see* Appendix A. The design conditions defined in 1.4 are to be complied with.

2.4.2 When the unit is to operate in an area which could result in the build-up of ice on the drilling derrick, the effects of ice loading are to be included in the calculations, *see* Pt 4, Ch 3. The design criterion for this condition may be taken as a non-drilling condition with defined setback loading. The environmental criteria are to be agreed with LR, but in general may be based on five-year return criteria for the operating location.

2.4.3 The structural design of the drilling derrick may be required by LR to include the effect of fatigue loading, *see* Pt 4, Ch 5.

2.4.4 Fatigue damage calculations for individual components when required are to take account of the degree of redundancy and also the consequence of failure.

2.4.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

(a) The design of the derrick or mast and associated ancillary equipment is to incorporate features to reduce the risk to personnel during routine maintenance or operations.
(b) The design is to allow for suitable and safe access from deck or installed work platforms for operation, maintenance and inspection services. All items in the derrick are to be accessible for routine inspection, without the need for man-riding winches.
(c) Where direct access to lubrication points such as crown or deflector sheaves cannot be provided, the use of remote grease lines can be incorporated.
(d) The design is to also allow for extra hang off points for temporary equipment such as wire line units.
(e) Portable equipment such as catwalk samson posts are also to be fitted with padeyes to allow safe removal and re-location.
(f) All padeyes are to be designed, installed and tested to LR requirements, and all padeyes are to be identified and a record book kept, allowing for inspection records to be maintained.
(g) Consideration is to be given to providing access and means to fight a major fire at the monkey board level. The means to fight a fire at this level are to include portable and fixed fire-fighting systems.
(h) Modification to any part of the derrick or mast from original design will require OEM and LR design approval, followed by trials if necessary.
(j) Temporary installed structures, members or fittings are to undergo an assessment by the dutyholder to confirm they will not affect the original design; if the design is affected, details are to be submitted for approval.
(k) Casing stabbing boards are to comply with the following requirements:
    - The hoisting system is to be designed and constructed to Codes and Standards approved by LR.
    - Permanent safe access to the stabbing board for operators and maintenance personnel is to be provided.
    - Any rack and pinion system is to be designed so that the working platform will not fall if the rack or pinion should fail, and a single or common mode failure cannot occur.
    - Where winch systems are used, the rope is to spool evenly on the drum and there are to be at least three full turns of rope remaining on the drum at all times.
    - The rope is to remain captive with the drum and sheave systems under all service conditions, including slack rope conditions.
    - Upper and lower-level limit switches are to ensure that the hoist system does not operate beyond its specified range.
    - Casing stabbing boards is to be clearly marked ‘SUITABLE FOR CARRYING PEOPLE’ and with the number of people they can carry.
    - Casing stabbing boards and other working platforms that are raised and lowered by a powered or manually operated system are to provide users with a secure and safe means of travel and support at the point of work.
    - The working platform is to be positively guided by rails or runners. The guidance system is to ensure that the platform remains captive to its rails or runners under all circumstances, including any wheel or roller failure or failure of the primary hoisting system.
    - Rails/runners are to be securely attached to their supports and are to not open up under static operations, travelling or other dynamic operations, overload testing or operation of the secondary control/braking system.
    - The working platform is to have non-slip standing surfaces, handrails, mid-rails and edge protection.
    - The platform is to also have anchorage points for inertia-type safety harnesses.
    - Control of the primary lifting system is to provide smooth movement of the working platform. The control lever is to spring to neutral on release, effectively braking the primary hoisting system.
    - Where a manual system of raising or lowering the platform is used, a positive locking system such as a ratchet-and-pawl mechanism is to be provided in addition to the service brake.
    - A secondary, inertia-type brake, acting at the rails, is to be provided in case there is any failure in the primary hoisting system. The secondary brake is to act independently of the primary brake and not require any power source (hydraulic, electrical or pneumatic) for its operation.
    - Each braking system is to be capable of holding the full rated capacity of the loaded stabbing board plus allowances for dynamic effects. It is not to be possible to lower the working platform by brake operation only. Two locking devices are to be provided, such that one locking device operates when the lifting handle is at neutral and the other one operates if the hoist mechanism fails. Each device is to be independent.
    - A speed controlling device is to prevent the raising and lowering speed of the platform exceeding tripping speed.
    - Adequate safety gear of the progressive type is to be provided, designed to engage within freefall conditions.
    - The platform is to be equipped with a latch lock mechanism which secures it when not in motion.

2.5 Water towers

2.5.1 Water towers on self-elevating units are to be designed in accordance with a recognised Code or Standard, modified to take into account the unit’s motions and marine environmental aspects, *see* Appendix A. Provisions for effective securing of towers when the unit is in transit is also to be similarly designed. The design conditions defined in 1.4 are to be complied with.

2.5.2 The structural design of the tower is to include the effect of fatigue loading, *see* Pt 4, Ch 5.

2.5.3 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.5.4 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.5.5 Wind loads are to be calculated in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME Code), or a recognised Code or Standard, *see* Appendix A.

2.5.6 The permissible stresses in the hull structure below the tower are to be in accordance with Pt 4, Ch 5.

2.6 Flares structures

2.6.1 Flares structures are to be designed in accordance with the requirements of a recognised Code or Standard, *see* Appendix A. The design conditions defined in 1.4 are to be complied with.

2.6.2 The flare structures are also to be designed for the imposed loads due to handling the structure and when in the stowed position.

2.6.3 The designers/Builders are to specify the maximum weight of the burner and spreader and the design criteria defined in 1.4.

2.6.4 The structural design of flare structures is to include the effect of fatigue loading and the thermal loads during flaring, *see* Pt 4, Ch 5.

2.6.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.6.6 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.6.7 Wind loads are to be calculated in accordance with LR's LAME Code or a recognised Code or Standard, *see* Appendix A.

2.6.8 Permissible stresses in the hull structure below the flare structure supports are to be in accordance with Pt 4, Ch 5.

2.7 Lifting appliances

2.7.1 Lifting appliances shall, as a minimum, meet the requirements of the following Standards and are to comply with LR's LAME Code, and where applicable, PUWER Reg 4 and LOLER Reg 5. *See also* Chapter 11.

API Spec 2C	*Specification for offshore pedestal mounted cranes*.
API RP 2D	*Operation and maintenance of offshore cranes*.
ASME B30.20	*Below-the-hook lifting devices*.

BOP handling systems will meet the minimum requirements of API Spec 7K.

Hoisting appliances are to be located such as to ensure safe operation, and must be suitably protected if for location in a hazardous area. Protection is to limit surface temperature to a maximum of 80 per cent of auto-ignition temperature. This temperature, if unknown, may be taken to be a maximum of 200°C.

Submitted design data for hoisting appliances is to include all load and hoisting/lowering speed combinations at the rope drum.

Man-riding winches are to be of an approved type and certified for offshore use, and they are to comply with the following requirements:

(a) Two fail safe brakes are to be provided, one automatic and the other manual.
(b) Hydraulic winches may be provided with a regenerative brake system with breaking valve, in place of a secondary manual brake.
(c) The operating lever is to be returned to neutral upon release in any position.
(d) Declutching devices are not to be fitted, unless otherwise agreed by LR, *see* (e).
(e) 'Sprag' type unidirectional bearings (freewheels) are acceptable subject to regular satisfactory in-service inspection.
(f) Lowering under normal operating conditions is to be through control of the motor.
(g) Means for prevention of overriding and underriding of the winch is to be provided, where reasonably practicable.
(h) Manufacturer's label indicating operational parameters and approval for man-riding.
(j) A sign affixed to the winch, clearly indicating suitability for man-riding (for example, 'SUITABLE FOR MAN-RIDING').
(k) The winch operating lever must automatically return to neutral when released.
(l) An automatic brake that will engage upon returning the operating lever to neutral.
(m) A manual brake.
(n) A guide for spooling the wire rope onto the drum (manual or automatic).
(o) The ability to lower the rider in a controlled manner in the event of loss of power to the winch.
(p) An emergency disconnect from the power source (ESD) located within winch operator's reach.

2.8 Guard rails and ladders

2.8.1 It is the Owners' responsibility to provide permanent access arrangements and protection by means of Ladders and guard rails. It is recommended that such arrangements are designed in accordance with a recognised Code or Standard.

2.8.2 Dutyholders should be aware that the hoops of a ladder alone may not be effective in safely arresting a fall without injury. Dutyholders are therefore advised to review their risk assessments and consider if additional fall protection is required or alternative means of access is to be supplied.

Where dutyholders choose to use fall arrest equipment inside a hooped ladder to arrest a fall, they should be aware that hoops may interfere with the operation of some types of fall arrest equipment (for example, inertia reel devices). Dutyholders should contact their manufacturer or supplier for advice on the performance of such equipment when used in a hooped ladder.

Users of fall arrest equipment inside a caged ladder should also be aware of the possibility of injury from striking the cage following a fall. The use of climbing helmets to reduce the risk of injury may need to be considered (refer to HSE CCID 1-2012).

Where ladders are used as (or part of) an emergency escape route, they are to be fire resistant to comply with BS 476 part 7, 1989 or equivalent.

Ladders fixed and portable are to be suitable for use in the intended areas, and the Owner is to conduct risk assessments with regard to the use of wooden or aluminium ladders in an offshore drilling environment.

Ladders used as an escape to sea are also to be included in the unit's inspection and maintenance planning.

2.9 Fire and blast loading

2.9.1 Particular consideration is to be given to the potential effects of fire and blast impinging on exposed boundary bulkheads of accommodation spaces and/or temporary refuge. Where boundary bulkheads can be subjected to blast loading, the scantlings are to comply with Pt 4, Ch 3,4.16 and Ch 6,9.1.6.

Other Standards which will apply to fire and blast loading include:

API RP 2FB *Recommended practice for design of offshore facilities against fire and blast loading*.

■ *Section 3*
Drilling plant systems

3.1 Plans and particulars

3.1.1 Plans and particulars showing arrangement of the drilling plant equipment, systems, functional descriptions and operating philosophies are to be submitted for approval. Where considered necessary, risk assessments are also to be submitted for consideration.

3.1.2 The submitted information is to include the following as applicable to the equipment categories:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations as applicable.
- Material specifications and welding details.

Drilling equipment is to be designed in accordance with internationally recognised and agreed Codes and Standards and in accordance with the requirements of Section 1.

3.1.3 The generally recognised Codes and Standards frequently specified for drilling equipment are included in these Rules. These Codes and Standards may be used for certification but the additional requirements given in these Rules apply and will take precedence over the Codes and Standards wherever conflict occurs.

3.1.4 The selected materials are to be suitable for the purpose intended and must have adequate properties of strength and ductility. Materials used in welded construction are to be of known and documented weldable quality.

3.1.5 For selection of acceptable materials suitable for hydrogen sulphide-contaminated products (sour service), reference is made to NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H2S-containing Environments in Oil and Gas Production*, *see* Appendix A.

3.1.6 Grey iron castings are not to be used for critical components.

3.1.7 Proposals to use spheroidal graphite iron castings for critical components operating below 0°C will be specially considered by LR in each case.

3.1.8 In general, bolts and nuts are to comply with the Standards listed in Appendix A, A1.2.

3.1.9 Bolts and nuts for major structural and mechanical components are to have a tensile strength of not less than 600 N/mm^2. Galvanising of high tensile bolts and nuts is to be avoided. Where non high tensile bolts and nuts are galvanised, they are to follow the guidelines of ASTM B695.

3.1.10 The risk of galvanic corrosion is also to be considered in the selection of all types of fasteners.

3.1.11 For general service, the specified tensile strength of bolting material is not to exceed 1000 N/mm^2.

3.1.12 Where required, materials of high heat resistance are to be used and the ratings are to be verified.

3.1.13 All bolted structures are to have specific installation and tensioning design requirements made available to the Owner and LR for review before assembly.

3.2 General requirements for piping systems

3.2.1 The design and construction of the piping systems, piping and fittings forming part of such systems are to be in accordance with an acceptable Code or Standard, *see* 1.5, and are also to comply with the remainder of this Section.

3.2.2 Piping systems for the drilling and well-testing installations are, in general, to be separate and distinct from piping systems essential to the safety of the unit. Notwithstanding this requirement, this does not exclude the use of the installation's main, auxiliary and/or essential services for drilling plant operations in suitable cases. Attention is drawn to the relevant Chapters of Part 5, Main and Auxiliary Machinery, when such services are to be utilised. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

3.2.3 Piping for services essential to the drilling operations, and piping containing hydrocarbon or other hazardous fluids, is to be of steel or other approved metallic construction. Piping material for H_2S-contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H2S-containing Environments in Oil and Gas Production*, *see* Appendix A.

3.2.4 All piping systems are to be suitable for the service intended and for the maximum pressures and temperatures to which they are likely to be subjected.

3.2.5 In mud, cement or other systems where the piping is likely to be subjected to considerable erosion, a suitable erosion allowance is to be specified, and anticipated service conditions such as vibration, velocity, hydraulic hammer pressure pulsations are also to be taken into account.

3.2.6 The number of detachable pipe connections in the drilling piping systems is to be limited to those which are essential for mounting and dismantling. Non-critical auxiliary systems such as water and air service may be attached with approved detachable couplings.

3.2.7 Valves used for the shutting down and control of equipment in an emergency, such as choke manifolds and standpipe manifolds, are to be provided with indicators to show clearly whether they are open or closed.

3.3 Flexible piping

3.3.1 Flexible piping elements approved for their Intended use may be installed in locations where rigid piping is unsuitable or impracticable. Such flexible elements are to be accessible for inspection and replacement, and are to be secured and protected so that personnel will not be injured in the event of failure.

3.3.2 All flexible hoses used during drilling operations are to be manufactured to a recognised Code or Standard and a prototype hose with end fittings attached is to have been burst-tested to the minimum pressure stipulated by the appropriate Standard. Transfer, mud, hydraulic and pneumatic hoses which may be liable to heavy external wear are to be specially protected. Protection against mechanical damage and from rushing/compression is to be provided where necessary.

3.3.3 Means are to be provided to isolate flexible hoses if used in systems where uncontrolled outflow would be critical.

3.3.4 Kill, choke and jumper hoses are to meet the minimum requirements of API 16C and API RP53.

3.3.5 Hydraulic control hoses serving well completion units and blow out preventers are to meet the requirements of API Spec 16E and API RP53.

3.3.6 Flexible piping is to meet the requirements of API RP 17B/ISO 13628-11:2007 *Recommended Practice for Flexible Pipe*. Inspection and maintenance procedures of flexible lines are to meet with requirements of API RP 7L.

3.3.7 Fiberglass and plastic pipe are to meet the requirements of the following main Standards and where applicable other standards in Appendix A:

API RP 15CLT	*Recommended practice for composite lined steel tubular goods.*
API Spec 15HR	*Specification for high pressure fiberglass line pipe.*
API Spec 15LE	*Specification for polyethylene line pipe (pe).*
API Spec 15LR	*Specification for low pressure fiberglass line pipe.*

3.4 Design and construction

3.4.1 The design strength of drilling equipment is to comply generally with LR agreed Codes and Standards.

3.4.2 Drilling equipment and systems are to be protected from excessive loads and pressures.

3.4.3 All drilling equipment is to be located in order to ensure safe operation, and must be suitably protected if for location in a hazardous area. Protection is to limit surface temperature to a maximum of 80 per cent of auto-ignition temperature. This temperature, if unknown, may be taken to be a maximum of 200°C.

3.4.4 The equipment is to be suitable for the design environmental conditions for the unit and the submitted design data for drilling equipment is to include all loading conditions, for each item, including the most unfavourable combination of loads, and any external loading conditions.

3.4.5 A dedicated area suitably sized and classified for well test equipment is to be provided. The area is to be suitably protected with bunding and drainage to prevent any oil spillage from spreading to other areas of the unit.

3.4.6 All areas that are intended to contain permanent or temporary equipment are to be designed with utilities such as electrical power, fresh water, compressed air, PA system, ESD, firewater and/or deluge system and communication system.

3.4.7 The drilling plant will be designed and constructed with regard to safe handling and storage of heavy equipment.

3.4.8 Suitable drilling plant control systems are to be provided; as a minimum, these are to display drilling data, audible and visual alarms, anti-collision systems status, necessary process and storage systems data and are to control the mechanical and electrical equipment and other necessary utilities for safe drilling operations.

3.4.9 The drilling plant is to be equipped with sufficient emergency stops in critical areas. Details of the drilling plant emergency alarm system are to be submitted to LR for review.

3.4.10 The drilling plant will be designed to reduce the potential of ignitions arising from static, lightning and stray currents.

3.5 Drilling equipment

3.5.1 All drilling equipment shall, as a minimum, meet the requirements of the following main Standards and where applicable other standards referenced in Appendix A.

Consideration is to be given during the design and installation of all drilling equipment to reducing the risk to personnel during routine maintenance or operations:

API Spec 7-1	*Specification for rotary drill stem elements.*
API Spec 7K	*Specification for drilling and well servicing equipment*.
API RP 7G	*Recommended practice for drill stem design and operating limits*.
API Spec 8A	*Specification for drilling and production hoisting equipment.*
API RP 8B	*Recommended practice for procedures for inspection, maintenance, repair, and remanufacture of hoisting equipment*.
API Spec 9A	*Specification for wire rope*.
API RP 9B	*Recommended practice on application, care and use of wire rope for oil-field service*.
API Spec 7F	*Oil-field chain and sprockets*.
API RP 7L	*Procedures for inspection, maintenance, repair, and remanufacture of drilling equipment*.
API Spec 8A	*Specification for drilling and production hoisting equipment*.
API RP 8B/ ISO 13534:2000	*Recommended practice for procedures for inspection, maintenance, repair, and remanufacture of hoisting equipment*.
API Spec 8C/ ISO 13535:2000	*Specification for drilling and production hoisting equipment (psl 1 and psl 2)*.
API Spec 9A	*Specification for wire rope.*
API RP 9B	*Recommended practice on application, care and use of wire rope for oil-field service*.
API RP 13C/ ISO 13501	*Recommended practice on drilling fluid processing systems evaluation*.
API RP 2003	*Protection against ignitions arising out of static, lightning and stray currents*.
API RP 7HU1	*Safe use of 2-Inch hammer unions for oilfield applications*.

3.6 Drilling well control equipment

3.6.1 Drilling well control equipment, including auxiliary well control equipment, is to meet the requirements of the following main Standards and where applicable other standards referenced in Appendix A.

3.6.2 Consideration during the design of the well control system to reducing the risk to personnel during routine maintenance or operations is to be undertaken.

3.6.3 Where surface BOPs are being used, a risk assessment on the need for an SID (sea bed isolation device) is to be submitted to LR for review.

3.6.4 The number of components and arrangement for the blow out preventer stack is to be presented to LR for review:

API Spec 16A/ ISO 13533:2001	*Specification for drill-through equipment*.
API Spec 16C	*Specification for choke and kill systems*.
API RP 16D	*Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment*.
API Spec 16F	*Specification for marine drilling riser equipment*.

API RP 16Q	*Recommended practice for design, selection, operation and maintenance of marine drilling riser systems*.
API Spec 16R	*Specification for marine drilling riser couplings*.
API Spec 16RCD	*Specification for drill through equipment rotating control devices*.
API RP 16ST	*Coiled tubing well control equipment systems*.
API RP 53	*Blowout prevention equipment systems for drilling wells*.
API RP 59	*Recommended practices for well control operations*.
API RP 64	*Recommended practices for diverter systems equipment and operations*.

■ *Section 4* Bulk storage wet and dry systems

4.1 General

4.1.1 The requirements for fired and unfired pressure vessels associated with the drilling plant and bulk storage vessels are to comply with the general requirements of Ch 8,4.

4.1.2 Pressure vessels are to comply with the design requirements in Ch 8,4.

4.1.3 Degasser and mud-gas separators are to be suitably constructed to handle the maximum design flow rate. All vented lines are to be of sufficient capacity and be vented to a safe location. Design particulars are to be submitted to LR for review.

4.1.4 Cementing units and associated high pressure pipes and manifolds are to be suitably designed and tested. If the cement unit is designed to be used as a kill unit, the components, specifications, capacities and power arrangements are to be supplied to LR for review.

4.1.5 The bulk system is to be designed to receive, store and deliver required volumes of bulk material to the mud and cementing system. Design capacities of the system are to be submitted for LR review.

4.1.6 Bulk storage vessels which penetrate watertight decks or flats are to be suitably reinforced, *see* Ch 3,2.10.

4.1.7 All bulk tanks, wet and dry, are to be designed for ease of cleaning and have adequate facilities for access and rescue of personnel.

4.2 Dry bulk systems

4.2.1 All dry bulk tanks are to be fitted with weight or volume indicators and a high level alarm. Provision for manual measurement is to also be made available.

4.2.2 The dry bulk vessels are to be designed for ease of cleaning and have adequate facilities for access and rescue of personnel.

4.2.3 All dry bulk lines (including ventilation lines) are to be designed for minimum flow resistance, minimum possible length and as few bends as possible. Connection points for purge air will be installed at critical flow areas in the bulk lines. Vent line outlets are to be kept as far as possible from HVAC inlets and normally manned areas.

4.2.4 The bulk air supply will be designed with redundancy and is to incorporate bulk air dryers. The compressors are to be located as close to the bulk storage tanks as possible.

4.2.5 The design is to prevent inadvertent mixing of cement and other bulk material.

4.2.6 All dry bulk storage vessels are to be equipped with safety valves or bursting discs to prevent damage due to overpressure. Bursting discs may only be used for vessels located in open areas or, if fitted in conjunction with a relief line, the discharge must be led to an open area.

4.2.7 For dry bulk storage vessels in enclosed areas, testable full open safety valves which can be vented out of the area are to be used. The enclosed areas where bulk storage vessels are located are to be ventilated such that a build-up of pressure will not occur in the event of a break or leak in the air supply system.

4.3 Wet bulk systems

4.3.1 Wet bulk storage tanks are to be suitably constructed with regard to the design maximum mud weight capacity of the vessel. All tanks are to be suitably equipped with equipment for preventing settling of mud.

4.3.2 The system will incorporate transfer systems with dedicated redundancy of pumps and manifolds. Sufficient by-passes with necessary valves for the liquid bulk in each storage tank are required. The systems are to be designed to transfer the relevant liquid bulk of design-specified weight and capacity to the liquid bulk tanks.

4.3.3 The design is to prevent inadvertent mixing of base oil and brine liquids.

4.3.4 High pressure mud pumps are to be fitted with pulsation dampers and relief valves set at the maximum allowable pressure of the system.

4.3.5 The mud pump relief line from the safety valve is to be self-draining and be as direct as possible with no bends and be suitably secured. The relief line after the relief valve is to be the same pressure rating as the pressure line before the relief valve. Facilities for flushing the vent lines are to be incorporated.

4.4 Mud mixing and storage system

4.4.1 The mud mixing and storage system is to be designed with sufficient capacity and structural strength to perform all planned mud mixing and storage operations with minimum risk of spillage or release of dust or fumes.

4.4.2 The entire mixing and storage system is to be designed for safe material handling and protection for personnel and the environment.

4.5 Mud treatment system

4.5.1 The mud treatment system is to be designed to operate without any risk to personnel with regard to spillage or exposure to hazardous substances.

■ *Section 5* Offshore safety and pollution

Dutyholders are to meet the requirements of the following main Standards and, where applicable, other standards referenced in Appendix A, or equivalent, as a minimum to ensure adequate safety to personnel and the environment.

API Spec 14A/ ISO 10432:2004	*Specification for subsurface safety valve equipment.*
API RP 14B/ ISO 10417:2004	*Recommended practice for design, installation, repair and operation of subsurface safety valve systems.*
API RP 14C	*Recommended practice for analysis, design, installation and testing of basic surface safety systems on offshore production platforms*.
API RP 14E	*Recommended practice for design and installation of offshore production platform piping systems*.
API RP 14F	*Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, division 1, and division 2 locations*.
API RP 14FZ	*Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, zone 0, zone 1, and zone 2 locations*.
API RP 14G	*Recommended practice for fire prevention and control on fixed open type offshore production platforms*.
API RP 14J	*Recommended practice for design and hazards analysis for offshore production facilities*.
API RP 49	*Recommended practice for drilling and well servicing operations involving hydrogen sulfide*.
API RP 54	*Recommended practice for occupational safety and health for oil and gas well drilling and servicing operations.*
API Std 2000	*Venting atmospheric and low-pressure storage tanks*.
API RP 76	*Contractor safety management for oil and gas drilling and production operations*.
API RP 75	*Recommended practices for development of a safety and environmental management program for offshore operations and facilities*.

■ *Section 6* Competence

Dutyholders are to ensure all their personnel are suitably trained and assessed with regard to their competence in performing their routine work and also with regard to emergency drills and duties.

■ *Section 7* Electrical installations

7.1 General

7.1.1 In general, electrical installations are to comply with the requirements of Pt 6, Ch 2.

7.1.2 Electrical equipment installed in areas where an explosive gas atmosphere may be present is to be in accordance with Pt 7, Ch 2 and Section 9 or an equivalent standard acceptable to LR.

Section 8 Control systems

8.1 General

8.1.1 In general, control engineering systems are to comply with the requirements of Pt 6, Ch 1 and/or with the appropriate Codes or Standards defined in Appendix A, as applicable.

8.1.2 The control aspects of the blow out preventer stack are to be in accordance with the requirements of 3.6.

8.1.3 Emergency shut-down systems and other safety and communication systems are to comply with the requirements of Pt 7, Ch 1.

Section 9 Fire, hazardous areas and ventilation

9.1 General

9.1.1 Hazardous areas and ventilation are to comply with Ch 3,3 and Pt 7, Ch 2.

9.1.2 The general requirements for fire safety are to comply with Pt 7, Ch 3.

9.1.3 A general arrangement drawing(s) of the unit, showing hazardous zones and spaces as well as the design philosophy is to be submitted to LR for review. The drawing is to refer to the requirements of Pt 7, Ch 2 and equivalent standards, for example:

API RP 14F *Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, division 1, and division 2 locations*.

API RP 14FZ *Recommended practice for design and installation of electrical systems for fixed and floating offshore petroleum facilities for unclassified and class I, zone 0, zone 1, and zone 2 locations*.

API RP 505 *Recommended practice for classification of locations for electrical installations at petroleum facilities classified as class 1, zone 0, zone 1, and zone 2*.

API RP 500 *Recommended practice for classification of locations for electrical installation at petroleum facilities classified as class 1, division 1 and division 2*.

IP Model code P15.

Section 10 Risks to personnel from dropped objects

10.1 Goal

10.1.1 The requirements of this Section are to ensure that risks to personnel from dropped objects, hereinafter referred to as DROPS, are continuously addressed, in so far as they affect the objectives of classification.

10.2 Class notation

10.2.1 Where the requirements of this Section are met to the satisfaction of LR, units will be eligible to be assigned the **DROPS** class notation. This notation will be retained as long as the preventive measures to protect personnel from hazards from dropped objects are found, upon examination at the prescribed surveys, to be maintained to the satisfaction of LR.

10.3 Scope

10.3.1 Each unit is required to have a DROPS management system in place and be relevant to the design and specifics of the unit.

10.3.2 The Builder or Owner will create a general arrangement drawing of critical DROPS areas which will be clearly displayed in general information areas throughout the unit and accommodation.

10.3.3 The DROPS GA drawing will identify each area with colour coding and will clearly indicate the criticality levels within areas of the unit. The colour criticality coding is to be assigned as follows:

(a) Green Zone:
Where the layout and activities of the area present little likelihood of personnel being exposed to potential dropped objects under normal circumstances.

(b) Yellow Zone:
Where the layout and activities of the area present some risk of personnel being exposed to potential dropped objects under normal circumstances.

(c) Red Zone:
Where the layout and activities of the area present significant risk of personnel being exposed to potential dropped objects under normal circumstances.

10.3.4 Zones are to be clearly displayed at all access points to the respective areas. All signs are to be pictorial to eliminate potential issues with different languages. Refer to BS EN IEC 62079:2001 Section 4.7.3.2 for further information.

10.3.5 All third party equipment, permanent or temporary, is to undergo a design risk assessment before installation. Records and methods of inspecting the third party equipment are to be maintained and available for LR review.

10.3.6 Suitable equipment and hand tools for working at height are to be provided. Details and records of inspection of such tools and equipment are to be maintained and available for LR review.

10.3.7 When the use of DROPS shelters are incorporated into the safety management system, full structural and installation details of the shelters, including the intended level of safety, are to be presented for LR review.

10.3.8 The preventive maintenance systems of the unit are to indicate where specialised work at height tooling is required for routine maintenance.

10.3.9 An inventory of permanent fixed equipment is to be created and maintained by the unit; the inventory is to include photographs and a description of each item. The photographs are to be taken from a distance and also from close up to avoid confusion with identification. Each individual item of equipment is to be identified by permanent marking or by the use of suitably attached durable labels.

10.3.10 An inventory of temporarily installed equipment is to be created and maintained by the unit. This will incorporate scheduled routine inspections to verify that no modifications, changes or damage to the equipment has occurred since the initial inspection on installation, or previous scheduled inspection.

10.3.11 A program of scheduled surveys and inspection will be created; methods and records of inspection and any remedial actions are to be maintained and available for LR review.

10.3.12 A record of failed items, with reason for failure, is to be maintained and is to be available for review by LR.

■ *Section 11* Trials

11.1 General

11.1.1 Before a new drilling plant (or any alteration or addition to an existing plant) is put into service, final drilling plant trials are to be carried out by an approved technical organisation, as defined in 11.2, to demonstrate that the integral drilling plant is suitable for safe operation and can operate as per the design.

11.1.2 The operational philosophy of the drilling plant is to be submitted for consideration. The operational philosophy is to include:

(a) each task to be performed, e.g., drilling operations, equipment inspection/maintenance, cleaning and instrument observation;
(b) a robust identification of the hazards associated with each task;
(c) the methods used to manage the identified hazards.

11.1.3 Where the operational aspects of the drilling plant have an effect on the overall safety of the drilling unit, the personnel on board or the environment, these aspects are to be to the satisfaction of LR.

11.1.4 The final drilling plant trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on an approved test schedule. The test schedule is to be submitted to LR for approval.

11.2 Approved technical organisation

11.2.1 An approved technical organisation, for the purposes of this Section, is one that can demonstrate that the trials are witnessed by competent experienced personnel with a minimum of 10 years' offshore operational drilling plant experience. CVs are to be submitted to LR for review. The approved technical organisation is to be acceptable to the Owner and LR.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to the process plant facility on board production and storage units as defined in Chapter 3. The process plant facility includes the equipment and supporting structure and systems used for oil and gas production including separation, treating and processing systems and equipment and systems used in support of production operations, where permitted by the national Flag Administration. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The Rules cover the design strength and safety aspects of the process plant facility installed on board production and storage units.

1.1.3 The operational aspects and reliability of the production and process plant facility are not covered by class except when they have an effect on the overall safety of the production unit, the personnel on board or the environment.

1.1.4 The Rules are framed on the understanding that a unit with an installed production and process plant facility will not be operated in environmental conditions more severe than those for the design basis and class approval.

1.1.5 It is the responsibility of the Owners/Operators to ensure that the production and process plant facility is properly maintained and operated by qualified personnel and that the test and operational procedures are clearly defined and complied with.

1.1.6 The limiting design criteria on which approval is based are to be stated in the unit's Operations Manual.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Production units with an installed process plant facility which comply with the requirements of this Chapter, or recognised Codes and Standards agreed with LR, will be eligible for the assignment of the special features class notation **PPF**.

1.2.3 When a production unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional descriptive note may be assigned in accordance with Pt 1, Ch 2.

1.3 Scope

1.3.1 The following additional topics applicable to the special features class notation are covered by this Chapter:

- Major equipment and structures of the production and process plant.
- Oil or gas processing system, including flowlines from the riser termination flanges, manifolds, production swivels, separators, heaters and coolers, relief and blow-down systems and water treatment systems.
- Production plant safety systems.
- Production plant utility systems.
- Riser compensating and tensioning system.
- Relief and flare system.
- Well control system.

1.3.2 Unless agreed otherwise with LR the Rules consider the following as the main boundaries of the production and process plant facility:

- Any part of the production and process system located on the unit including the riser connecter valve or christmas tree but excluding the risers is considered part of the facility.
- The shut-down valve at the export outlet from the production or process plant to the storage or offloading facility.
- The outlet from hydrocarbon flare and vent system.

1.4 Plant design characteristics

1.4.1 The design and arrangements of the process plant are to comply with the requirements of this Chapter and with recognised Codes and Standards, *see* 1.5.

1.4.2 Attention is to be given to the relevant Statutory Regulations of the National Administration in the country of registration and the area of operation, as applicable.

1.4.3 The plant and supporting structures above the deck are to be designed for all operating and transit conditions in accordance with recognised and agreed Codes or Standards, suitably modified to take into account the unit's motions and marine environmental aspects. Except for the emergency condition, as detailed in 1.4.4, the total stress in any component of the plant is not to exceed the Code value at the temperature concerned, unless expressly agreed otherwise by LR, whether the plant is operative or non-operative, when subjected to any possible combination of the following loads, as applicable:

(a) Static and dynamic loads due to wave-induced motions of the unit.
(b) Loads resulting from hull flexural effects at the plant support points, as appropriate.
(c) Direct wind loads.
(d) Normal gravity and functional loads.
(e) Thermal loads, as appropriate.
(f) Ice and snow loads, as appropriate.

1.4.4 In general, the plant and supporting structures above the deck are to be designed for an emergency static condition with the unit inclined to the following angle:

- Column-stabilised and tension-leg units:
  25° in any direction.
- Surface type units:
  22,5° heel, port and starboard, and trimmed to an angle of 10° beyond the maximum normal operating trim.
- Self-elevating units:
  17° in any direction in transit conditions only.

These angles may be modified by LR in particular cases as considered necessary. In no case is the inclined angle for the emergency static condition to be taken less than the maximum calculated angle in the worst damage condition in accordance with the appropriate damage stability criteria.

1.4.5 In the emergency condition defined in 1.4.4, the plant is to be assumed to have maximum operating weights, temperatures and pressures unless agreed otherwise with LR. When applicable, the plant is also to be subjected to ice and snow loads. Wind loads need not be considered to be acting during this emergency condition. The total stress in any component of the plant or support structure above the deck is not to exceed the minimum yield stress of the material.

1.4.6 The permissible stresses in the primary hull structure below plant and equipment supports are to be in accordance with Pt 4, Ch 5.

1.5 Recognised Codes and Standards

1.5.1 Installed process plant facility designed and constructed to standards other than the Rule requirements will be considered for classification, subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements. It is essential that in such cases LR is informed of the Owner's proposals at an early stage in order that a basis for acceptance of the standards may be agreed. *See* Appendix A for applicable international Codes and Standards considered by LR as an equivalent level of safety to Rule requirements.

1.5.2 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for the production and process plant as defined in Appendix A. Other Codes and National Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.5.3 Where necessary, the Codes are to be suitably modified and/or adapted to take into account all marine environmental aspects.

1.5.4 The agreed Codes and Standards may be used for design, construction and installation but where considered applicable by LR, compliance with the additional requirements stated in the Rules is required. Where there is any conflict the Rules will take precedence over the Codes or Standards.

1.5.5 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.6 Equipment categories

1.6.1 The approval and certification of production and process plant equipment are to be based on equipment categories agreed with LR.

1.6.2 Production and process plant equipment including its associated pipes and valves is to be divided into equipment Categories **1A**, **1B** and **II,** depending on the complexity of manufacture and its importance with regard to the safety of personnel and the installation and the possible effect on the environment.

1.6.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety, for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in category **1A**.

II Equipment related to safety which is normally manufactured to recognised Codes and Standards and has proven reliability in service but excludes equipment in category **1A** and **1B**.

1.6.4 A guide to equipment and categories is given in Appendix A. A full list of equipment categories for each production and process plant facility is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.7 Equipment certification

1.7.1 Equipment is to be certified in accordance with the following requirements:

(a) **Category 1A**
- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of a certificate of conformity.

(b) **Category 1B**
- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/pressure/load tests and issue of certificate of conformity.

(c) **Category II**
- Supplier's/manufacturer's works' certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.7.2 All equipment recognised as being of importance for the safety of personnel and the production and process plant facility is to be documented by a data book.

1.8 Fabrication records

1.8.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records should include the following:
- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examinations.
- Load, pressure and functional test reports.

1.9 Installation of plant equipment

1.9.1 The installation of equipment on board the unit is to be controlled by LR in accordance with the following principles:
- All Category **1A** and **1B** equipment delivered to the unit is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other necessary documentation.
- All Category **II** equipment delivered to the unit is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed production and process plant.
- Monitoring of functional tests after installation on board in accordance with an approved test programme.
- Issue of a plant installation report.

1.10 Maintenance and repair

1.10.1 It is the Owner's/Operator's responsibility to ensure that installed production and process plant is maintained in a safe and efficient working condition in accordance with the manufacturer's specification.

1.10.2 When it is necessary to repair or replace installed production and process plant, any repaired or spare part is to be subject to the equivalent certification as the original.

1.11 Plans and data submissions

1.11.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter. Plans are to be submitted in triplicate, but only a single copy of supporting documents and calculations is required.

■ *Section 2* Structure

2.1 Plans and data submissions

2.1.1 The following additional plans and information are to be submitted:
- General arrangement plans of the plant layout.
- Plans and design calculations as required for derricks in Ch 7,2, when appropriate.
- Structural plans of equipment skids and design calculations.
- Structural plans of equipment support frames and trusses and design calculations.
- Flare structures and design calculations.

2.2 Materials

2.2.1 Materials are to comply with Ch 1,4 and material grades are to comply with Pt 4, Ch 2 using the categories defined in this Section.

2.2.2 Support structures for the production and process plant are to be divided into the following categories:
- Primary structure.
- Secondary structure.

2.2.3 Some specific examples of structural elements which are considered as primary structure are as follows:

- Module main frame members and deck support stools.
- Main legs and chords including end connections.
- Foundation bolts.

2.3 Miscellaneous structures

2.3.1 The design loadings for all structures supporting plant, including equipment skids, support frames and trusses, are to be defined by the designers/Builders and calculations are to be submitted in accordance with an appropriate Code or Standard, *see* Appendix A. The design requirements of 1.4 are to be complied with.

2.3.2 The design of process plant support structures should integrate with the primary hull under-deck structure.

2.3.3 The permissible stresses in the hull structure below the production and process plant are to be in accordance with Ch 3,2 and Pt 4, Ch 5,2.

2.4 Flare structures

2.4.1 Flare structures are to be designed for an emergency condition and for normal operating conditions as defined in 1.4 and in accordance with an appropriate Code or Standard, *see* Appendix A.

2.4.2 The flare structures are also to be designed for the imposed loads due to handling the structure and when in the stowed position.

2.4.3 The designers/Builders are to specify the maximum weight of the burner and spreader and the design criteria defined in 1.4.

2.4.4 The structural design of flare structures is to include the effect of fatigue loading and the thermal loads during flaring, *see* Pt 4, Ch 5.

2.4.5 Where National Administrations give specific requirements with respect to fatigue design, it is the responsibility of the Owners to comply with such Regulations.

2.4.6 For slender structures and components, the effects of wind induced cross-flow vortex vibrations are to be assessed.

2.4.7 Wind loads are to be calculated in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (hereinafter referred to as LAME Code) or a recognised Code or Standard, *see* Appendix A.

2.4.8 Permissible stresses in the hull structure below the flare structure supports are to be in accordance with Pt 4, Ch 5.

2.5 Lifting appliances

2.5.1 Lifting appliances used for handling flare structures and blow out preventers are to be in accordance with LR's LAME Code, *see also* Chapter 11.

2.6 Guard rails and ladders

2.6.1 It is the Owners' responsibility to provide permanent access arrangements and protection by means of ladders and guard rails. It is recommended that such arrangements are designed in accordance with a recognised Code or Standard.

■ *Section 3* **Production, process and utility systems**

3.1 Plans and particulars

3.1.1 Plans and particulars showing arrangement of production, process and utility systems and equipment listed in 1.3, and diagrammatic plans of the associated piping systems, are to be submitted for approval.

3.2 General requirements for piping systems

3.2.1 The design and construction of the piping systems, piping and fittings forming parts of such systems are to be in accordance with a recognised Code or Standard, *see* 1.5, and are also to comply with the remainder of this Section.

3.2.2 Piping systems for the production and process plant are, in general, to be separate and distinct from piping systems essential to the safety of the unit. Notwithstanding this requirement, this does not exclude the use of the unit's main, auxiliary and/or essential services for process plant operations in suitable cases. Attention is drawn to the relevant Chapters of Part 5, Main and Auxiliary Machinery, when such services are to be utilised. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

3.2.3 All piping systems are to be suitable for the service intended and for the maximum pressures and temperatures to which they are likely to be subjected.

3.2.4 The number of detachable pipe connections in hydrocarbon production and process piping is to be limited to those which are necessary for installation and dismantling. The pipe connections are to be suitable for the intended use.

3.2.5 Soft-seated valves and fittings which incorporate elastomeric sealing materials installed in systems containing hydrocarbons or other flammable fluids are to be of a fire-tested type.

3.2.6 The production and process system piping is to be protected from the effects of fire, mechanical damage, erosion and corrosion. Corrosion coupons or test spool pieces are to be designed into the system. Spool pieces are to be fitted in such a manner as to be easily removed or replaced. Sand probes and filters should be provided where necessary for extraction of sand or reservoir fracture particles.

3.2.7 The corrosion allowance for hydrocarbon production and process piping of carbon steel is not to be less than 2 mm.

3.2.8 Piping for services essential to the production and process operations, and piping containing hydrocarbon or other hazardous fluids is to be of steel or other approved metallic construction. Piping material for H_2S-contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 - *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production*, *see* Appendix A.

3.2.9 Arrangements are to be made to isolate the unit from the supply and discharge of produced oil and gas by the provision of suitable shut-down valves on the unit and at the receiving installation. The valves on board the unit are to be operable from the control stations as well as locally at the valve.

3.2.10 If a single failure in the supply from utility systems such as compressed air or cooling water which are essential to the operation of the production and process plant could cause an unacceptable operating condition to arise, an alternative source of supply is to be provided.

3.2.11 Process vessel washout connections are to be fitted with non-return valves in addition to the shut-off valves.

3.2.12 The locking open/closed of valves is to be by means of a suitable keyed locking device operated under a permit-to-work system.

3.2.13 For process vessels which periodically require isolation prior to gas-freeing and personnel entry, pipelines which connect the vessel to a source of pressure and/or hazardous fluid are to be provided with isolating valves, bleed arrangements and means to blank off the open end of the pipe. For systems containing significant hazards, consideration is to be given to double block and bleed valves and blanking-off arrangements.

3.2.14 For ship units and other surface type units, the design of piping systems should take into consideration the effect of hull girder bending.

3.3 Flexible piping

3.3.1 Flexible piping elements approved for their intended use may be installed in locations where rigid piping is unsuitable or impracticable. Such flexible elements are to be accessible for inspection and replacement, and are to be secured and protected so that personnel will not be injured in the event of failure.

3.3.2 Short lengths of flexible hose may be utilised to allow for limited misalignment or relative movement. All flexible hoses are to be manufactured to a recognised Code or Standard, and a prototype hose with end fittings attached is to have been burst-tested to the minimum pressure stipulated by the appropriate standard. Protection against mechanical damage is to be provided where necessary.

3.3.3 Means are to be provided to isolate flexible hoses if used in systems where uncontrolled outflow would be critical.

3.4 Christmas tree

3.4.1 The christmas tree is to have at least one remotely-operated, self-closing master valve and a corresponding wing valve for each penetration of the tree. In addition, there is to be a closing device for each penetration at a level higher than the wing outlets.

3.4.2 Additional wing outlets such as injection lines are to penetrate the christmas tree above the lowest remotely-operated master valve, and be fitted with a remotely-operated, self-closing control valve and a check valve installed as close as possible to the injection point. The injection point for hydrate inhibitor may be fitted below the lowest self-closing master valve if the christmas tree is fitted with valve(s) below this point.

3.4.3 All valves in the vertical penetrations of the christmas tree are to be capable of being opened and kept in the open position by means of an external operational facility independent of the primary actuator.

3.4.4 Valves that are important in connection with the emergency shut-down system such as the master and wing valves are to be fitted locally with visual position indicators.

3.4.5 Where exposure to H_2S-contaminated products is likely, materials and welds shall meet the requirements of the NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production*.

3.5 Protective pressure relief

3.5.1 Process vessels, equipment and piping are to be provided with pressure-relieving devices to protect against system pressures exceeding the maximum allowable pressure such that the system will remain safe under all foreseeable conditions, unless the system is designed to withstand the maximum pressure which can be exerted on it under any circumstances. Where appropriate, sections of the production and process system are to be protected against underpressure resulting from a change of temperature or state of the contents, *see also* 4.9.

3.5.2 The pressure-relieving devices are to be sized to handle the expected maximum relieving rates due to any single failure or fire incident. The rated discharge capacity of any pressure-relieving device is to take into account the back pressure in the vent system.

3.5.3 For protected items or sections of the system not in continuous service, a single pressure-relieving device is acceptable. Block valves for maintenance purposes, where fitted, in the pressure relief lines are to be interlocked with the source of pressure or spare relief valves as applicable.

3.5.4 For any particular item or section of the system in continuous service at least two pressure relief possibilities are to be provided for operational and maintenance purposes. In this case, each pressure relief possibility is to be designed to handle 100 per cent of the maximum relieving rate expected unless alternative systems are available or short-term shut-down is acceptable.

3.5.5 If more than two pressure relief possibilities are provided on any particular item or section of the system in continuous service, and any pressure relief possibility is designed to handle less than 100 per cent of the maximum relieving rate expected, the arrangements are to be such as to allow any one device to be isolated for operational and maintenance purposes without reducing the capacity of the remaining devices below 100 per cent of the maximum relieving rate.

3.5.6 Block valves fitted in pressure relief lines for isolation purposes are to be of the full-flow type, capable of being locked in the fully open position by an approved keyed method.

3.5.7 The arrangement in 3.5.4 or 3.5.5 is to ensure that all relief possibilities cannot be isolated from the system at the same time, by interlocking the block valves using an approved keyed method of interlocking operated under a permit-to-work system.

3.5.8 The set pressure for all pressure-relieving devices should generally not exceed the design pressure of the protected system or item. Pressure relief valves are to be sized such that any accumulation of pressure from any source will not exceed 110 per cent of the design pressure.

3.5.9 Bursting discs fitted in place of, or in series with, a pressure relief valve are to be rated to rupture at a pressure not exceeding the design pressure of the protected system or item. However, in the case of a bursting disc fitted in parallel with a relief valve(s), such as in vessels containing substances which may render a pressure relief valve inoperative or where rapid rates of pressure rise may be encountered, the bursting disc is to be rated to burst at a maximum pressure not exceeding 1,3 times the design pressure of the vessel at the operating temperature.

3.5.10 Pressure-relieving devices are normally to be connected to the flare and relief header to minimise the escape of hydrocarbon fluids, and to ensure their safe collection and disposal. Where appropriate, vent and discharge piping arrangements are to be such as to avoid the possibility of a hazardous reaction between any of the fluids involved.

3.5.11 In circumstances where hazardous vapours are released directly to the atmosphere, the outlets are to be arranged to vent to a safe location where personnel would not be endangered.

3.5.12 The inlet piping to a pressure relief device should be sized so that the pressure drop from the protected item to the pressure relief device inlet flange does not exceed three per cent of the device set pressure.

3.5.13 Pressure-relieving devices and all associated inlet and discharge piping are to be self-draining. Open vents are to be protected against ingress of rain or foreign bodies.

3.5.14 Relief piping supports are to be designed to ensure that reaction forces during relief are not transmitted to the vessel or system, and to ensure that relief devices are not used as pipe supports or anchors where the resultant forces could interfere with the proper operation of the device.

3.5.15 The design and material selection of the pressure-relieving devices and associated piping is to take into consideration the resulting low temperature, vibration and noise when gas expands in the system.

3.5.16 Positive displacement pumps and compressors for hydrocarbon oil/gas service are to be provided with relief valves in closed circuit, set to operate at a pressure not exceeding the maximum allowable pressure of the pump or equipment connected to it, and adequately sized to ensure that the pump output can be relieved without exceeding the system's maximum allowable pressure. Proposed alternatives to relief valves may be considered and full details should be submitted.

3.5.17 Relief valves may also be required on the suction side of pumps and compressors when recycling from the discharge side is possible.

3.6 Flaring arrangements

3.6.1 Facilities for gas flaring and oil burning are to be adequate for the flaring requirements during well control, well testing and production operations. For well testing, at least two flare lines are to be arranged through which any flow from the well may be directed to different sides of the unit.

3.6.2 The flare system is to be designed to ensure a clean, continuous flame. Provision is to be made for the injection of make-up gas into the vent system to maintain steady flaring conditions. A means of cooling the flare burners when used for well testing is to be available.

3.6.3 The flare burners are to be located at a safe distance from the unit. This distance, or protection zone, is to be determined by consideration of the calculated thermal radiation levels. For limiting thermal radiation levels, *see* 3.9.

3.6.4 For well test systems, any flare line or other line downstream of the choke manifold is to have an inside diameter not less than the inside diameter of the largest line in the choke manifold.

3.6.5 Production and process plant venting systems are to be led to a liquid separator or knock-out drum to remove any entrained liquids which cannot be safely handled by the flare. Where a liquid blowdown system is provided, adequate provision is to be made in the design for the effects of back pressure in the system, and for vapour flash-off when the pressures in the blowdown system are reduced.

3.6.6 The flare system is to be capable of controlling any excess gas pressures resulting from emergency depressurising conditions.

3.7 Depressurising system

3.7.1 All production and process plant in which significant volumes of hydrocarbon liquids and gases with potential for incident escalation can be blocked in during a fire is to be capable of being depressurised. The capacity of the system should be based on evaluation of:

- system response time;
- heat input from defined accident scenarios;
- material properties and material utilisation ratio;
- other protection measures, e.g., active and passive fire protection;
- system integrity requirements.

3.7.2 The emergency depressurising system is to be designed to reduce pressures to a level to prevent rupture of the pressure-containing components. As a minimum requirement, the depressurising system is to be designed to ensure that the pressure is reduced to half the equipment's maximum allowable working pressure or 6.9 bar, whichever is lower, within approximately 15 minutes.

3.7.3 The cooling effect due to throttling of large volumes of high pressure gas in the discharge piping and valves during the depressurising period is to be evaluated for appropriate material selection. Where temperatures below minus 29°C are expected, the piping and valve material is to have specified average Charpy V-notch impact values of 27J minimum at the calculated lowest operational temperature.

3.7.4 The vent system design should ensure that allowance has been given to the possibility of high dynamic forces at pipe bends and supports during emergency depressurisation.

3.8 Cold vents

3.8.1 A cold vent is acceptable only if it is determined that the gas release will not create any danger to the unit. Due consideration should be given to the prevailing wind to ensure that gases do not flow down around operating areas. Where cold venting is provided, the arrangement is to minimise:

- Accumulation of toxic and flammable gases.
- Ignition of vent gases from outside sources.
- Flashback upon accidental ignition of the vent gases.

3.8.2 In order to avoid continuous burning of the vent gases in the case of accidental ignition, an extinguishing system using a suitable inert gas is to be installed.

3.8.3 The dew point of the gases is to be such that they will not condense at the minimum ambient temperature. In the case of liquid condensation in the cold vent piping, a drain or liquid collection system is to be provided to prevent accumulation of liquid in the vent line.

3.9 Radiation levels

3.9.1 The location and designed throughput of the flare is to take into consideration the levels of thermal radiation to ensure that exposure of personnel, structure and equipment is acceptable even under unfavourable wind conditions.

3.9.2 Under normal operating circumstances, the intensity of thermal radiation, including solar radiation, in unprotected areas where personnel may be continuously exposed is not to exceed 1,9 kW/m^2 in calm conditions. Allowance for the cooling effect of wind in unsheltered areas may be taken into consideration in determining the radiation levels.

3.9.3 Under emergency flaring conditions, the intensity of thermal radiation at muster stations and in areas where emergency actions of short duration may be required by personnel is not to exceed 4,7 kW/m^2 in calm conditions.

3.9.4 Suitable radiation screens, water screening or equivalent provision should be utilised to protect personnel, structure and equipment as necessary.

3.10 Firing arrangements for steam boilers, fired pressure vessels, heaters, etc.

3.10.1 The requirements of this Section are applicable to all types of fired equipment associated with the process plant. The equipment is to be constructed, installed and tested to the Surveyor's satisfaction.

3.10.2 Details of the design and construction of the fuel gas burning equipment for steam boilers, oil and gas heater furnaces, etc., are to be in accordance with agreed Codes, Standards and specifications normally used for similar plants in land installations, suitably modified and/or adapted for the marine environment. Ignition of the burners is to be by means of permanently installed igniters, or properly located and interlocked pilot burners and main burners arranged for sequential ignition.

3.10.3 Proposals to burn gas or gas/air mixtures having relative densities compared with air at the same temperature greater than one will be specially considered in each case. *See also* Pt 5, Ch 16.

3.10.4 Proposals for the furnace purging arrangements prior to ignition of the burners are to be submitted. Such arrangements are to ensure that any accidental leakage of product liquid or gas into the furnace, from a liquid or gas heating element, or from the accidental ingestion of flammable gases and/or vapours, does not result in hazardous conditions.

3.10.5 Compartments containing fired pressure vessels, heaters, etc., for heating or processing hazardous substances are to be arranged so that the compartment in which the fired equipment is installed is maintained at a higher pressure than the combustion chamber of the equipment. For this purpose, induced draft fans or a closed system of forced draught may be employed. Alternatively, the fired equipment may be enclosed in a pressurised air casing.

3.10.6 The fired equipment is to be suitably lagged. The clearance spaces between the fired equipment and any tanks containing oil are to be not less than 760 mm. The compartments in which the fired equipment is installed are to be provided with an efficient ventilating system.

3.10.7 Smoke box and header box doors of fired equipment are to be well fitted and shielded, and the uptake joints made gastight. Where it is proposed to install dampers in the uptake gas passages of fired equipment, the details are to be submitted. Dampers are to be provided with a suitable device whereby they may be securely locked in the fully open position.

3.10.8 Each item of fired equipment is to have a separate uptake to the top of the stack casing. Where it is proposed to install process fired equipment with separately fixed furnaces converging into a convection section common to two or more furnaces and/or a secondary radiant section at the confluence of the fired furnace uptake to the convection section, the proposed arrangements, together with the details of the furnace purging and combustion controls, are to be submitted.

3.11 Drain systems

3.11.1 Drainage systems are to be provided to collect and direct drained or escaped liquids to a location where they can be safely handled or stored. In general, equipment is to be provided with a hard-piped, closed drainage system for small quantities of produced liquids, an open system handling drainage from hazardous areas, and an open system handling drainage from non-hazardous areas. These systems are to be entirely separate and distinct.

3.11.2 The hazardous drainage systems are to be kept separate and distinct from those of the main and auxiliary machinery systems. Consideration will be given to directing the process facilities hazardous drains to the facilities oil storage tanks. The hazardous drains fluids should not be allowed to free-fall into the tank. In units equipped with an inert gas system, a U-seal of adequate height, or equivalent method, should be arranged in the piping leading to the oil storage tanks.

3.11.3 Provision is to be made for protection against over-pressurisation of a lower pressure drainage system when connected to a higher pressure system.

3.12 Bilge and effluent arrangements

3.12.1 Where, during operation, the production plant spaces contain, or are likely to contain, hazardous and/or toxic substances, they are to be kept separate and distinct from the unit's main bilge pumping system. This does not, however, preclude the use of the unit's main bilge system when the production plant is shut down, gas freed or otherwise made safe.

3.12.2 The bilge and effluent pumping systems handling hazardous and/or toxic substances should, wherever possible, be installed in the space associated with the particular hazard. Spaces containing pumping systems that take their suctions from a hazardous space will also be designated as hazardous spaces unless all associated pipelines are of all-welded construction without flanges, valve glands and bolted connections, and the pump is totally enclosed.

3.12.3 Bilge and effluent piping systems related to the production plant are to be constructed of materials suitable for the substances handled, including any accidental admixture of such substances.

3.12.4 Arrangements are to be provided for the control of the bilge and effluent pumping systems installed in production and process plant spaces from within the spaces and from a position outside the spaces.

■ *Section 4* Pressure vessels and bulk storage

4.1 General

4.1.1 The Rules in this Section are applicable to fired and unfired pressure vessels associated with process plant, and drilling plant defined in Chapter 7.

4.1.2 Pressure vessels are to be designed in accordance with Pt 5, Ch 10 and Ch 11 or with internationally recognised and agreed Codes and Standards and in accordance with the requirements of Section 1.

4.1.3 The list in Appendix A, A 1.2.11 gives reference to some generally recognised Codes and Standards frequently specified for drilling and production equipment. These Codes and Standards may be used for certification but the additional requirements given in the Rules apply and the Rules will take precedence over the Codes and Standards wherever conflict occurs.

4.1.4 Portable gas cylinders and other pressure vessels used to transport liquids or gases under pressure are to comply with an acceptable National or International Standard.

4.1.5 Where pressure parts are of such an irregular shape that it is impracticable to design their scantlings by the application of recognised formulae, the acceptability of their construction is to be determined by hydraulic proof testing and strain gauging or by an agreed alternative method.

4.2 Plans and data submissions

4.2.1 Design documentation is to be submitted for all pressure vessels.

4.2.2 The submitted information is to include the following:

- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations for normal operating and emergency conditions.
- Bill of Materials including material specifications as necessary.
- Fabrication specifications including welding, heat treatment, type and extent of NDE.

4.3 Equipment certification

4.3.1 Equipment certification is to be carried out in accordance with Section 1 and equipment categories are to comply with Table A 2.3 in Appendix A.

4.4 Materials

4.4.1 Materials for pressure vessels are to comply with Ch 1,4 and the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), except where modified by this Section.

4.4.2 Welded carbon/manganese (C–Mn) steels used for major pressure containing parts should have a chemical composition limited by the carbon content and the carbon equivalent:

Carbon content $C \leq 0{,}25$

When the elements in the following formula are known, this formula is to be used:

Carbon Equivalent:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \leq 0{,}45$$

Symbols are as defined in the Rules for Materials.

4.4.3 The use of material not meeting these limitations is subject to special consideration in each case. The welding of such materials normally requires more stringent fabrication procedures regarding the selection of consumables, preheating and post weld heat treatment.

4.4.4 Materials for pressure containing parts are to be tested at the temperature specified in Table 13.4.1 in Chapter 13 of the Rules for Materials and shall achieve a minimum energy of 27J for materials with specified minimum yield strength less than or equal to 360 MPa and 42J for higher strength materials.

4.4.5 Equipment and components required for hydrogen sulphide sour service shall meet the property requirements of NACE MR0175/ISO15156 – *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production*.

4.4.6 Materials employed in liquefied natural gas pressure vessels are to be impact tested in accordance with Pt 4, Ch 2.

4.5 Design pressure and temperature

4.5.1 The design pressure is the maximum permissible working pressure and is not to be less than the highest set pressure of the safety valve. If the design of the system is such that it may be possible for it to see a vacuum, the design pressure shall also consider the minimum working pressure which the system may see.

4.5.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operating conditions.

4.5.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

4.5.4 The design temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when the plans of the pressure part are being considered. For fired steam boilers, T is to be taken as not less than 250°C.

4.6 Design safety factors

4.6.1 The term 'allowable stress', σ, is the stress to be used in the formulae for calculating the scantlings of pressure vessels.

4.6.2 The allowable stress used for the design of a pressure vessel is to be in accordance with the Code or Standard being used to design that vessel.

4.6.3 Pressure vessels are to be designed for the emergency conditions referred to in 1.4.

4.6.4 It is not permissible to use the allowable stress levels of one Code or Standard to determine the scantlings using the formulae from a different Code or Standard.

4.6.5 The yield strength used in the determination of allowable stress or in calculations is not to exceed 0,85 of the specified minimum tensile strength of the material in question.

4.7 Construction and testing

4.7.1 Fabrication documentation is to be compiled by the manufacturer simultaneously with the fabrication in a systematic and traceable manner so that all the information regarding the design specification, materials, fabrication processes, inspection, heat treatment, etc., can be readily examined by the Surveyor.

4.7.2 Welding procedures and construction requirements for welding shall be in accordance with those specified in Chapters 12 and 13 of the Rules for Materials.

4.7.3 Procedures for performing non-destructive examination and the acceptance criteria to be applied shall be in accordance with Chapter 13 of the Rules for Materials.

4.8 Hydrostatic test pressure

4.8.1 Pressure vessels are to be subject to a hydrostatic test in accordance with the applied Code, Standard, or specification before being taken into service.

4.8.2 The hydrostatic test pressure is to be a minimum of 1,5 x design pressure if not specified in the Code or Standard.

4.8.3 The pressure and holding time are to be recorded.

4.8.4 Primary general membrane stresses are in no case to exceed 90 per cent of the minimum yield strength of the material.

4.9 Protective and pressure relief devices

4.9.1 Pressure vessels are to be provided with protective devices so that they remain safe under all foreseeable conditions.

4.9.2 Where pumps and pressure surges are capable of developing pressures exceeding the design conditions of the system, effective means of protection such as pressure relief devices or equivalent are to be provided.

4.9.3 Pressure relief valves are to be sized such that any accumulation of pressure from any source will not exceed 121 per cent of the design pressure. For specific fire contingencies where accumulated pressure could exceed 121 per cent, design proposals will be specially considered.

4.9.4 Bursting discs fitted in place of or in series with safety valves are to be rated to burst at a maximum pressure not exceeding the design pressure of the vessel at the operating temperature. Bursting discs are only to be used for pressure vessels located in open areas or if fitted in conjunction with a relief line led to an open area.

4.9.5 Where a bursting disc is fitted downstream of a safety valve, the maximum bursting pressure is also to be compatible with the pressure rating of the discharge system.

4.9.6 In the case of bursting discs fitted in parallel with relief valves to protect a vessel against rapid increase of pressure, the bursting disc is to be rated to burst at a maximum pressure not exceeding 1,3 times the design pressure of the vessel at operating temperature.

4.9.7 Pressure relief devices are to be type tested to establish their discharge capacities at their maximum rated design pressures and temperatures in accordance with an approved Code or Standard.

4.9.8 Where pressure relief devices can be isolated from the pressure vessel whilst in service, there is to be an alternative independent pressure relief device. The system pressure relief valve set pressure and bursting disc rupture pressure should be displayed at the respective operating position.

4.9.9 Any isolating valves used in conjunction with pressure relief devices are to be the full flow type capable of being locked in the full open position. Where isolating valves are arranged downstream and upstream of a relief device they are to be interlocked with each other.

4.9.10 Where pressure relief devices are duplicated on the same vessel or system and fitted with isolating valves, these valves are to be so interlocked as to ensure that before one relief device is isolated the other relief device is fully open and the required discharge capacity is maintained. The interlocking system is to be submitted for approval.

4.9.11 The design of the pressure-relieving system is to take into account the characteristics of the fluid handled and any extreme environmental condition recorded for the geographical zone of operation. The vent and pressure relieving systems are to be self-draining.

4.9.12 The rated discharge capacity of any pressure relief device is to take into account the back pressure in the vent systems. Where hazardous vapours are discharged directly to the atmosphere, the outlets are to be arranged to vent to a safe location.

4.10 Bulk storage vessels

4.10.1 Bulk storage vessels are to be designed in accordance with the general requirements of this Section and with one of the internationally recognised Codes or Standards for fusion welded pressure vessels quoted in Appendix A, A1.2.11, and in accordance with the design requirements given in Section 1, *see also* Ch 7,3.10.

4.10.2 For bulk storage vessels in enclosed areas, testable safety valves are to be used, which can be vented out of the area. Such enclosed areas are to be ventilated so that a pressure build-up will not occur in the event of a break or a leak in the air supply system.

4.10.3 Bulk storage vessels are normally to be supported by suitable skirts in order to distribute the loads into the supporting structure.

4.10.4 Bulk storage vessels which penetrate watertight decks or flats are to be suitably reinforced, *see* Ch 3,2.10.

■ *Section 5* Mechanical equipment

5.1 General

5.1.1 The Rules in this Section are applicable to all types of mechanical equipment associated with the production and process plant, with the exception of pressure vessels which are dealt with in Section 4.

5.1.2 Mechanical equipment is to be designed in accordance with internationally recognised and agreed Codes and Standards and in accordance with the requirements of Section 1.

5.1.3 The list in Appendix A, A1.2 gives reference to some generally recognised Codes and Standards frequently specified for drilling and production equipment. These Codes and Standards may be used for certification, but the additional requirements given in these Rules apply and will take precedence over the Codes and Standards wherever conflict occurs.

5.1.4 Production and process plant equipment is to be suitable for the service intended and for the maximum loads, pressures, temperatures and environmental conditions to which the system may be subjected.

5.2 Plans and data submissions

5.2.1 Design documentation for mechanical equipment is to be submitted in accordance with the equipment categories and certification requirements defined in Section 1.

5.2.2 The submitted information should include the following, as applicable to the equipment categories:
- Design specification, including data of working medium and pressures.
- Minimum/maximum temperatures, corrosion allowance, environmental and external loads.
- Plans, including sufficient detail and dimensions to evaluate the design.
- Strength calculations as applicable.
- Material specifications and welding details.

5.3 Equipment certification

5.3.1 Equipment categories and certification of production and process plant equipment are to be in accordance with the requirements of Section 1.

5.3.2 A general guide to specific equipment categories are given in Table A 2.3 in Appendix A.

5.3.3 Hoisting and pipe handling equipment are to comply with Ch 7,6.

5.3.4 Associated equipment such as oil engines, electric motors, generators, turbines, etc., are to comply with the applicable Sections of the Rules.

5.4 Materials

5.4.1 Materials are to comply with Ch 1,4 and the Rules for Materials, except where modified by this Section.

5.4.2 The selected materials are to be suitable for the purpose intended and must have adequate properties of strength and ductility and materials to be welded shall be of weldable quality.

5.4.3 As a minimum, Charpy impact tests are required to be carried out at the minimum design temperature (MDT) and exhibit minimum impact energies of 34J for minimum specified yield strengths of up to 360 MPa and 40J for higher yield strengths. For equipment used in LNG applications, the impact test temperature and energy requirements are to be in accordance with Pt 4, Ch 2.

5.4.4 For selection of acceptable materials suitable for hydrogen sulphide contaminated products (sour service), reference is to be made to the ISO 15156/NACE Standard in Appendix A, A1.2.21.

5.4.5 Grey iron castings are not to be used for critical components.

5.4.6 Proposals to use spheroidal graphite iron castings for critical components operating below 0°C will be specially considered by LR in each case.

5.4.7 In general, bolts and nuts are to comply with the Standards listed in Appendix A, A1.2.

5.4.8 Bolts and nuts for major structural and mechanical components are to have a tensile strength of not less than 600 N/mm^2.

5.4.9 For general service the specified tensile strength of bolting material should not exceed 1000 N/mm^2.

5.4.10 Where required, materials of high heat resistance are to be used and the ratings are to be verified.

5.5 Design and construction

5.5.1 The design strength of production and process plant equipment is to comply generally with Part 5, as applicable, and with LR agreed Codes and Standards.

5.5.2 All equipment included in this Section is to be suitable for the design environmental conditions for the unit.

5.5.3 Combustion equipment and combustion engines are not normally to be located in a hazardous area, unless the air space is pressurised to make the area non-hazardous in accordance with the following criteria:

- Pressurisation air is to be taken from a safe area.
- An alarm is to be fitted to indicate loss of air pressure.
- An air lock system with self-closing doors is to be fitted.
- The exhaust outlet is to be located in a non-hazardous area, and be fitted with spark arresters, *see* 5.5.4.
- The combustion air inlet is to be located in a non-hazardous area.
- Automatic shut-down is to be arranged to prevent over-speeding in the event of accidental ingestion of flammable gases or vapours.

5.5.4 Efficient spark arresters, of LR approved type, are to be fitted to the exhaust from all combustion equipment, except from exhaust gas turbines. Water cooled spark arresting equipment is to be fitted with means to give a warning in the event of failing cooling water supply.

5.5.5 Exhaust gases are to be discharged so that they will not cause inconvenience to personnel or a dangerous situation during helicopter operations.

5.5.6 The equipment and systems are to be designed, installed, and protected so as to be safe with regard to the risk of fire, explosions, leakages and accidents.

5.5.7 For any equipment using magnetic bearings, a system overview of magnetic bearing systems fitted to the equipment is to be submitted to LR for information. Any equipment which uses active magnetic bearings is to be supplied with a back-up system, such that in the event of a power failure of the active magnetic system the equipment can be brought to a safe condition. Details of the back-up system are to be submitted to LR for approval. If the back-up system has a finite life then the manufacturer is to advise LR and the Owner what the life of the back-up system is. The Owner is to ensure that the life of the back-up system is monitored, so that the equipment is not operated beyond the life of the back-up system.

■ *Section 6*
Electrical installations

6.1 General

6.1.1 In general, electrical installations are to comply with the requirements of Pt 6, Ch 2.

6.1.2 Electrical equipment installed in areas where an explosive gas atmosphere may be present is to be in accordance with Pt 7, Ch 2.

■ *Section 7*
Control systems

7.1 General

7.1.1 In general, control engineering systems are to comply with the requirements of Pt 6, Ch 1 and/or the appropriate Codes and Standards defined in Appendix A.

7.1.2 Emergency shut-down systems and other safety and communication systems are to comply with the requirements of Pt 7, Ch 1.

■ *Section 8*
Fire, hazardous areas and ventilation

8.1 General

8.1.1 Hazardous areas and ventilation are to comply with Ch 3,3 and Pt 7, Ch 2.

8.1.2 The general requirements for fire safety are to comply with Pt 7, Ch 3.

■ *Section 9*
Riser systems

9.1 General

9.1.1 Production riser systems which comply with the requirements of Chapter 12 will be eligible for the special features class notation **PRS**.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to units with installed dynamic positioning systems, and are additional to those applicable in other Parts of these Rules.

1.1.2 A unit provided with a dynamic positioning system in accordance with these Rules will be eligible for an appropriate class notation which will be recorded in the ClassDirect Live website.

1.1.3 Requirements, additional to these Rules, may be imposed by the National Authority with whom the unit is registered and/or by the administration within whose territorial jurisdiction it is intended to operate. Where national legislative requirements exist, compliance with such regulations is also necessary.

1.1.4 For the purpose of these Rules, dynamic positioning means the provision of a system with automatic and/or manual control capable of maintaining the heading and position of the unit during operation within specified limits and environmental conditions.

1.1.5 For the purpose of these Rules, the area of operation is the specified allowable position deviation from the desired set point, *see* 1.3.2.

1.2 Classification notations

1.2.1 Units complying with the requirements of this Chapter will be eligible for one of the following class notations, as defined in Pt 1, Ch 2:

DP(CM)	*See* Section 2.
DP(AM)	*See* Section 3.
DP(AA)	*See* Section 4.
DP(AAA)	*See* Section 5.

1.2.2 The notations given in 1.2.1 may be supplemented with a Performance Capability Rating (PCR). This rating indicates the calculated percentage of time that a unit is capable of maintaining heading and position under a standard set of environmental conditions (North Sea), *see* Section 6.

1.2.3 Additional descriptive notes may be entered in the ClassDirect Live website, indicating the type of position reference system, control system, etc.

1.2.4 Where a **DP** notation is not requested, dynamic positioning systems are to comply with the requirements of Section 2, as far as is practicable.

1.3 Information and plans required to be submitted

1.3.1 The following information and plans are to be submitted in triplicate. The Operation Manuals specified in 1.3.8 are to be submitted in a single set.

1.3.2 Details of the limits of the area of operation and heading deviations, together with proposals for redundancy and segregation provided in the machinery, electrical installations and control systems, are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail or in the event of fire or flooding, *see also* 1.3.6 and Sections 4 and 5.

1.3.3 Where a common power source is utilised for thrusters, details of the total maximum load required for dynamic positioning are to be submitted.

1.3.4 Plans of the following, together with particulars of ratings in accordance with the relevant Parts of the Rules, are to be submitted for:

(a) Prime movers, gearing, shafting, propellers and thrust units.
(b) Machinery piping systems.
(c) Electrical installations.
(d) Pressure vessels for use with dynamic positioning system.

1.3.5 Plans of control, alarm and safety sytems, including the following, are to be submitted:

(a) Functional block diagrams of the control system(s).
(b) Functional block diagrams of the position reference systems and the environmental sensors.
(c) Details of the electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
(d) Details of the monitoring functions of the controllers, sensors and reference systems, together with a description of the monitoring functions.
(e) List of equipment with identification of the manufacturer, type and model.
(f) Details of the control systems, e.g., control panels and consoles, including the location of the control stations.
(g) Test schedules (for both works' testing and sea trials) that are to include the methods of testing and the test facilities provided.

1.3.6 For assignment of a **DP(AA)** or **DP(AAA)** notation, a Failure Mode and Effects Analysis (FMEA) is to be submitted, demonstrating that adequate segregation and redundancy of the machinery, the electrical installation and the control systems have been achieved in order to maintain position in the event of equipment failure, *see* Section 4, or fire or flooding, *see* Section 5. The FMEA is to take a formal and structured approach and is to be performed in accordance with an acceptable and relevant National or International Standard, e.g., IEC 60812.

1.3.7 Where the **DP** notation is to be supplemented with a Performance Capability Rating (PCR), *see* 1.2.2, the following information is to be submitted for assignment of a PCR:
(a) Lines plan.
(b) General arrangement.
(c) Details of thruster arrangement.
(d) Thruster powers and thrusts.

1.3.8 Details of the intended modes of operation are to be submitted. As a minimum these are to include:
(a) a description of all the intended operating modes;
(b) details of the system configuration required for each mode of operation. When applicable, this is to include the configuration needed to meet the FMEA requirements of 1.3.6; and
(c) the procedures which are to be followed in each operating mode during normal and abnormal conditions.

1.3.9 A set of the operation and maintenance manuals is to be placed and retained on board the unit.

■ *Section 2* Class notation DP(CM)

2.1 General

2.1.1 The requirements for class notation **DP(CM)** are given in Pt 7, Ch 4,2 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which are to be complied with where applicable.

■ *Section 3* Class notation DP(AM)

3.1 Requirements

3.1.1 The requirements for class notation **DP(AM)** are given in Pt 7, Ch 4,3 of the Rules for Ships, which are to be complied with where applicable.

3.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable.

3.1.3 A manually initiated emergency alarm, clearly distinguishable from all other alarms associated with the dynamic positioning system, is to be provided at the dynamic positioning control station to warn all relevant personnel in the event of a total loss of dynamic positioning capability. In this respect consideration is to be given to additional alarms being provided at locations such as the Master's accommodation and operational control stations.

■ *Section 4* Class notation DP(AA)

4.1 Requirements

4.1.1 The requirements for class notation **DP(AA)** are given in Pt 7, Ch 4,4 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 5* Class notation DP(AAA)

5.1 Requirements

5.1.1 The requirements for class notation **DP(AAA)** are given in Pt 7, Ch 4,5 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 6* Performance Capability Rating (PCR)

6.1 Requirements

6.1.1 The requirements for PCR are given in Pt 7, Ch 4,6 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 7* Testing

7.1 General

7.1.1 The requirements for testing are given in Pt 7, Ch 4,7 of the Rules for Ships, which are to be complied with where applicable.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to offshore units with positional mooring systems.

1.1.2 The requirements apply to the following categories of unit and mooring type:

- Ship units, column-stabilised units, offshore loading buoys and other similar type moored floating structures.
- Multi-leg mooring systems, either spread-moorings or single-point moorings.
- Catenary systems or taut-leg systems.

1.1.3 Other types of application will be specially considered.

1.1.4 The requirements of this Chapter are not applicable to the mooring tethers on tension-leg units. For the design requirements of tension-leg units, *see* Pt 4, Ch 5.

1.1.5 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration of the coastal state(s) with territorial jurisdiction over the waters in which it is intended to operate.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 For the assignment of the character letter **T** to floating offshore installations at a fixed location with positional mooring systems, the requirements of this Chapter are to be complied with. Mobile offshore units provided with a positional mooring system which complies with the requirements of this Chapter will be eligible for the assignment of a special features class notation as follows:

PM (Positional mooring system), or

PMC (Positional mooring system for mooring in close proximity to other vessels or installations. This notation will apply in particular to any unit operating adjacent to a fixed installation, e.g., crane unit, accommodation unit, support unit, etc.).

1.2.3 The positional mooring system will be considered for classification on the basis of operating constraints and procedures specified by the Owner or Operator and recorded in the Operations Manual.

1.2.4 Units fitted with a thruster-assisted positional mooring system, which complies with the requirements of Section 4, will be eligible for the assignment of one of the following special features class notations:

TA(1)
TA(2)
TA(3)

1.2.5 The numeral in parentheses after the thruster-assist notation **TA** in 1.2.4 defines the thruster allowance which may be permitted in the design of the positional mooring system and is determined by the capacity/redundancy of the thrust/machinery installation, *see* Sections 4, 14 and 15.

1.3 Definitions

1.3.1 The definitions given in this Section are for Rule application only and will not necessarily be valid in any other context, *see also* Pt 1, Ch 2.2.

1.3.2 **Offshore Unit**. Floating structure permanently moored at a specific location.

1.3.3 **Ship**. Floating structure such as shuttle tanker or loading/offloading tanker which is to be temporarily moored to an offshore unit.

1.3.4 **Positional mooring**. Station-keeping by means of multi-leg mooring system with or without thruster-assist. The positional mooring system will consist of the following components, as relevant:

(a) Anchor points:
- Drag embedment anchors.
- Anchor piles.
- Suction anchor piles.
- Gravity anchors.
- Plate anchors.

(b) Anchor lines.

(c) Anchor line fittings:
- Shackles.
- Connecting links/plates.
- Rope terminations.
- Clump weights.
- Anchor leg buoyancy elements.

(d) Fairleads/bending shoes.

(e) Chain or wire rope stoppers.

(f) Winches or windlasses.

Where applicable, the structural or mechanical connection of these items to the unit is also considered to be part of the positional mooring system.

1.3.5 **Thruster-assist**. The use of thrusters, inclusive of their associated equipment, to supplement the unit's positional mooring system.

1.3.6 **Catenary mooring**. A mooring system which derives its compliancy mainly from the catenary action of the anchor lines. Some additional resilience is provided by the characteristic axial elasticity of the anchor lines.

1.3.7 **Taut-leg mooring**. A mooring system based on light-weight anchor lines pre-tensioned to a taut configuration with no significant catenary shape at any unit offset, and applying vertical and horizontal loads at the anchor points. With this type of system, compliancy is derived from the inherent axial elastic stretch properties of the anchor line.

1.3.8 **Single-point mooring**. An offshore mooring facility based on a single buoy or single tower, *see* Ch 2,1.2.6.

1.3.9 **Spread mooring**. A multi-line mooring system designed to maintain an offshore unit on an approximately fixed heading.

1.4 Plans and data submission

1.4.1 The positional mooring system will be subject to review and approval. The following information and plans are to be submitted in triplicate, to cover the design review and class approval of the positional mooring system:

(a) Plans of the positional mooring system and associated equipment are to be submitted including the following, as applicable:
- General arrangement of floating unit.
- Mooring layout.
- Field layout.
- Anchor lines and fittings.
- Anchor points.
- Fairleads/bending shoes.
- Cable stoppers.
- Winches, windlasses or tensioners.

(b) For thruster-assisted positional mooring systems, plans of the following together with particulars of ratings, in accordance with the relevant Parts of these Rules are to be submitted:
- Prime movers, gearing, shafting, propellers and thrust units, *see also* Part 5.
- Machinery piping systems.
- Electrical installations.

(c) In addition, details of proposals for the redundancy provided in machinery, electrical installations and control systems are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail. Where a common power source is utilised for thrusters, details of the total maximum load required for thruster-assist are to be submitted.

(d) Plans of control, alarm and safety systems including the following are to be submitted:
- Functional block diagrams of the control system(s).
- Functional block diagrams of the position reference systems and environmental sensors.
- Details of electrical supply to the control system(s), the position reference system(s) and the environmental sensors.
- Details of the monitoring functions of the controllers, sensors and reference system together with a description of the monitoring functions.
- List of equipment with identification of the manufacturer, type and model.
- Details of the overall alarm system linking the centralised control station, subsidiary control stations, relevant machinery spaces and operating areas.
- Details of control stations, e.g., control panels and consoles, including the location of the control stations.
- Factory and customer acceptance test schedules which are to include the methods of testing and the test facilities provided.

1.4.2 Single copies of the following supporting plans, data, calculations or documents are to be submitted:

(a) General:
- Mooring design premise.
- Moored unit details (dimensions and main particulars).

(b) Specifications:
- Materials.
- Equipment and fittings.
- Model testing.

(c) Data reports:
- Environmental criteria.

and in addition for floating offshore installations at a fixed location:
- Sea bed conditions.
- Soil and soil conditions.

(d) Design reports and calculations:
- Hydrodynamic/motion analysis.
- Mooring analysis.
- Model test results.
- Design load report.
- Anchor line components: strength and fatigue.

- Anchor point: strength and fatigue.
- Anchor point holding capacity.
- Fatigue.
- Equipment/ancillaries including the associated equipment, stoppers and fairleads: strength and fatigue.
- Corrosion protection and/or corrosion allowance.

(e) Other information:
- In-service inspection programme.

and in addition for floating offshore installations at a fixed location:
- Installation procedures.
- Installation records for piles and anchors, *see also* Ch 14,5.

and in addition for mobile offshore units:
- Anchor point holding capacity.

1.4.3 An Operations Manual, as required by Ch 1,3, is to be submitted and the manual is to contain all necessary information and instructions regarding positional mooring and, where relevant, thruster-assisted positional mooring. It would normally also contain descriptions of the following:
- Mooring systems.
- Laying the mooring system.
- Anchor pre-loading.
- Pre-tensioning anchor lines.
- Tension adjustment.
- Winch/windlass performance.
- Winch/windlass operation.
- Procedure in event of failure or emergency.
- Procedure for operating thrusters.
- Fault-finding procedures for thruster-assist system.
- Maintenance procedures.

■ *Section 2* Survey

2.1 General requirements

2.1.1 Positional moorings, with or without thruster-assist, are to be inspected and tested during manufacture/construction and under working conditions on completion of the installation.

2.1.2 The scope of inspection and/or testing to be carried out at the manufacturer's works is to be agreed with Lloyd's Register (hereinafter referred to as LR) before the work is commenced.

2.1.3 The general requirements for Periodical Surveys, contained in Pt 1, Ch 2 of the Rules, are to be complied with.

■ *Section 3* Environmental conditions

3.1 General

3.1.1 The Owner/Operator or designer is to specify the environmental criteria for which the unit is to be considered. The extreme environmental conditions applicable to the location, or operating areas are to be specified, together with all operating environmental limits. Detailed specialist environmental reports are to be submitted, with sufficient supporting information to demonstrate the validity of the limiting criteria, *see* 3.3.

3.1.2 A comprehensive set of operating and extreme environmental limiting conditions is to be submitted. This is to cover the following cases, as applicable, and any other conditions relevant to the system under consideration:
- Extreme environmental conditions.
- Limiting environmental conditions in which the unit and/or ship may remain moored.
- Limiting environmental conditions in which the unit and/or ship's main operating functions may be carried out (e.g., production and/or transfer of product).
- Limiting environmental conditions in which the unit and/or ship may (re)connect.

3.2 Environmental factors

3.2.1 The following environmental factors are to be considered in the design of the positional mooring system:
- Water depth range.
- Wind, including gust spectral characteristics and squall characteristics if relevant.
- Significant wave height.
- Wave period.
- Wave spectral characteristics.
- Current.
- Relative angles between wind, wave and current.
- Marine growth.
- Air and sea temperatures.

and in addition for floating offshore installations at a fixed location:
- Sea bed conditions.
- Soil conditions.

3.2.2 In certain locations the following factors may need to be considered in the design of the positional mooring system:
- Ice.
- Seismic events, such as earthquakes.

3.3 Metocean data

3.3.1 As part of the environmental data, the following metocean data will normally be required to be submitted:

- 100 (or 50 for mobile offshore units), 10 and 1-year return period values for wind-speed, significant wave height and current.
- Directional data for extreme values of wind, waves and current.
- Wave height/period joint frequency distribution (wave scatter diagram).
- Wave spectral parameters.
- Wind/wave/current angular separation data.
- Current speed and/or directional variation over the water depth.
- Long-term wave statistics by direction.
- Squall time series data where relevant.

3.4 Environmental parameters

3.4.1 **Water depth**. Minimum and maximum still water levels are to be determined, taking full account of the tidal range, sea bed subsidence, wind and pressure surge effects. For floating offshore installations at a fixed location, data is to be submitted to show the variation in water depth in way of the installation. This data is to be referenced to a consistent datum and is to include, where relevant, the water depth in way of each anchor or pile, gravity base or foundation, pipeline manifold, and in way of the radius swept by an attached ship.

3.4.2 **Wind**. The one-hour wind speed, plus wind gust spectrum, will normally require to be applied in design. The following wind gust spectra formulations can be adopted for the time varying component:

- API RP 2A.
- Other published spectra formulations may be accepted, *see* Appendix A, A1.2.17.

In areas where squalls are prevalent, a representative set of squall wind time series data which includes speed and directional characteristics should also be employed.

Estimating wind forces and moments for design input into analysis or model basin wind fields should preferably be done on the basis of wind tunnel tests using an accurate project-specific model.

3.4.3 **Waves**:

(a) To ensure that the most critical combinations of low frequency and wave frequency response are determined, a broad range of sea states represented by significant wave heights and peak periods will require to be investigated, preferably based on the use of a 100-year contour (or 50-year contour for mobile offshore units).

(b) For this approach, a wave contour of significant wave height and peak period combinations will require to be developed, using appropriate extrapolation techniques, to extend shorter term wave height and period joint frequency distribution data. Appropriate methods of developing the wave contour are to be used, *see* Appendix A, A1.2.18.

(c) The method of determining the wave contour is to be documented and included with the design submission package. Where adequate wave height/period joint distribution data is not available to enable such a contour to be produced, a conservative choice of wave period range will require to be applied in the design.

(d) As the wave spectrum is a combination of wind-driven waves and swell, consideration will need to be given for certain locations, to the joint occurrence and angular separation between these two components.

3.4.4 **Current**. Design current velocities are to be established, taking account of all relevant components including the following:

- Tidal currents.
- Circulation currents.
- Wind driven current.
- Storm surge generated current.

3.4.5 **Marine growth.** Account is to be taken in the design of build-up of marine growth on the anchor lines, riser system and/or the hull, and the resulting increase in load and damping. The thickness of marine growth taken into account is to be stated in the Operations Manual and is not to be exceeded in service.

3.4.6 **Air and sea temperature.** The minimum and maximum air and sea temperatures are to be specified in accordance with Chapter 1.

3.4.7 **Sea bed conditions**. For floating offshore installations at a fixed location, the sea bed conditions at the proposed locations of the anchor points and along the anchor line corridors are to be determined to provide data for the design of the anchoring system. Requirements for site investigation are contained in Chapter 14.

3.4.8 **Soil conditions**. For floating offshore installations at a fixed location, the soil conditions at the proposed locations of the anchor points are to be determined to provide data for the design of the anchoring system. Requirements for site investigation are contained in Chapter 14.

3.4.9 **Sea ice and icebergs**. The design philosophy of units intended to be moored in regions subject to sea ice or icebergs will require to be defined, including any quick-release mooring system arrangements.

3.4.10 **Seismic**. The requirements for units intended to be moored in regions subject to seismic events, such as earthquakes or tsunamis, will be subject to special consideration.

Section 4
Design aspects

4.1 Design cases

4.1.1 The positional mooring system, with or without thruster-assist, is to be designed for the following:

(a) **Intact Case:**
- This case assumes all anchor lines to be effective. Thruster-assist from an approved system can be included, *see* 4.2.

(b) **Damaged Case:**
- This case involves the failure of a single component, i.e., failure of an anchor line or anchor point, or failure of a component in the case of thruster-assist.
- Note that a single failure in the thruster system could lead to stoppage of several, or all, of the thrusters.

(c) **Transient Case:**
- The transient case will not normally require to be investigated.

4.2 Thruster-assist systems

4.2.1 Thrusters can be used to reduce the mean load on the mooring system, provide damping of low frequency surge motion, and/or control the heading of the unit, in order to limit the overall excursions. Thruster intervention allowances for supplementary thruster-assist notations are given in Table 10.4.1.

Table 10.4.1 Thruster allowance

Case	Thruster allowance		
	TA(1)	**TA(2)**	**TA(3)**
Operating (Intact)	None	70% of all thrusters	All thrusters
Survival (Intact)	70% of all thrusters	All thrusters	All thrusters
Operating (Single line failure)	None	70% of all thrusters	All thrusters
Survival (Single line failure)	70% of all thrusters	All thrusters	All thrusters

NOTES
1. The conditions for assignment of supplementary notations TA(1), TA(2) and TA(3) are defined in Section 14.
2. Net thrust values can be applied in the calculations, to the extent indicated in the Table. The basis for deductions due to thruster-hull, thruster-current and thruster-thruster interference is to be documented and included in the design submission.
3. Refer to 4.1.1 for the Rule basis of failure, including thruster system failure, for damaged case.

4.2.2 Units which utilise thruster-assistance, as an aid to position keeping or as a means of reducing anchor line tensions which have a system approved by LR, may be assigned a special features notation as defined in 1.2.

4.2.3 The requirements of Sections 14 and 15 are to be complied with and for the majority of offshore units with positional mooring systems which utilise thruster-assistance the class notation **TA(3)** will be applicable. Thruster-assist notations **TA(1)** and **TA(2)** will only be considered for applications of low criticality.

4.3 Design environmental conditions

4.3.1 Unless agreed otherwise with LR, the following design environmental combinations are to be considered:

(a) For floating offshore installations at a fixed location:
100-year sea state + 100-year wind + 10-year current.
For mobile offshore units:
50-year sea state + 50-year wind + 10-year current.

(b) For floating offshore installations at a fixed location:
100-year sea state + 10-year wind + 100-year (or 50-year for mobile offshore units) current.
For mobile offshore units:
50-year sea state + 10-year wind + 50-year current.

Joint probabilities of the various environmental actions may be taken into account if such information is available and can be adequately documented.

4.3.2 For 100-year (or 50-year for mobile offshore units) waves, a range of different wave height/period combinations will require to be considered, *see* 3.4.3.

4.3.3 For a unit and/or ship designed to disconnect from the mooring system, appropriate lower limiting environmental conditions can be applied for the connected cases.

4.3.4 The mooring system with the unit and/or ship disconnected is normally required to be designed for the criteria specified in 4.3.1.

4.3.5 For directional combinations, *see also* 4.4.

4.3.6 For locations where squalls are prevalent and unless otherwise agreed with LR, in addition to cases (a) and (b) in 4.3.1, sample squall time series data with the peak wind speed in the time series at the 100-year level are to be considered. The return period level of the concomitant sea state and current are to be agreed with LR.

4.4 Directional combinations

4.4.1 Sufficient combinations of directions of wind and current relative to wave direction are to be investigated to ensure the critical cases are found. Swell is to be superimposed from the worst case direction, *see* 3.4.3(d). The following combinations are envisaged as a minimum for design (unless joint directional probabilities of the various environmental actions are available and can be adequately documented):

(a) Wave, wind and current collinear.

(b) Wind and current at 30° to waves.

(c) Wind at 30° to waves, and current at 90° to waves.

NOTE

For case (c) above, only combination (a) given in 4.3.1 has to be considered.

4.4.2 When squalls are considered, the time history of the squalls is to include also the variation of the wind direction, *see* 3.4.2. The range of concomitant wave and current directions is to be agreed with LR.

4.5 Environmental directions relative to unit and mooring system

4.5.1 For spread moored units, at least head, quartering, beam and down-line directions are to be considered in mooring analysis. Dependent on response analysis and wind, wave and current force/moment calculations, other directions may require to be considered, *see also* 4.4.

4.5.2 For weathervaning units, the following cases must be considered as a minimum requirement:

- Wave direction along mooring line.
- Wave direction between mooring lines.

4.5.3 Where the mooring lines are grouped, additional wave directions will require to be considered at intermediate headings between the directions given above.

4.5.4 For a positional mooring system without thruster-assist, two conditions will normally need to be analysed:

- loss of highest loaded line leading to highest excursions; and
- loss of second highest loaded line leading to highest line tensions.

4.5.5 When squalls are considered, the approach with regard to the enviromental directions relative to the unit is to be agreed with LR. As the direction of the wind during a squall can change significantly, a key consideration is the wind direction at the time of the peak wind speed.

4.6 Other design aspects

4.6.1 Anchor lines are to have adequate clearance from subsea equipment such as templates, flowlines, etc.

4.6.2 The design of the mooring system is to take account of the offset limits required by the drill string or riser system, and the avoidance of contact between risers and anchor lines.

4.6.3 Where production, or other normal operational activity, is intended to be continued during periods where an anchor line is disconnected for inspection, etc., specific environmental limitations are to be established to ensure that safety factors are maintained even with one line out of action. A similar procedure applies when machinery and equipment cannot remain fully functional during maintenance and inspection.

4.6.4 Wherever practicable, permanent moorings are to be designed to allow removal for repair in reasonable weather of damaged components without seriously reducing the overall safety of the unit as a whole.

4.6.5 In cases where the mooring system is intended to be actively controlled by adjustment of line lengths and tensions, satisfactory evidence must be submitted to show that the adjustment procedure is practical, taking account of winch control and prevailing environmental conditions.

4.6.6 Where units are moored in areas where high velocity currents occur, dynamic excitation due to vortex shedding is to be considered.

4.6.7 Hawse pipes used in the mooring system are to have adequate strength for the imposed loads and when located inside tanks are to be considered for sloshing forces.

■ *Section 5* **Design analysis**

5.1 General

5.1.1 A comprehensive analysis will be required in all cases and model tests are normally to be performed for ship shape units or unique designs. Validation will be required for each part of the analysis process, by correlation with model tests or other proven method.

5.2 Model testing

5.2.1 The model test programme and test facilities are to be to LR's satisfaction.

5.2.2 The model is to be of an adequate scale and is to fully represent the moored unit. Account is to be taken of the different draughts, deck structures and large equipment appendages such as anchor racks or thrusters. In case of (ultra) deep water moorings, the scale and representation of the moorings will be subject to special consideration.

5.2.3 The tests are to be of sufficient duration to establish the low frequency behaviour, and most probable maxima with sufficient reliability.

5.2.4 The tests are to include means of establishing the effects of green water and/or slamming, through video recordings of the model testing, and by measurement of the following:

- Relative motions.
- Forces on local panels mounted at various locations such as bow area and accommodation.

5.2.5 It is recommended that an initial analysis be performed prior to the start of the model test programme, in order to understand and clarify the conceptual design, and to help focus the model testing on the most important design parameters.

5.3 Analysis aspects

5.3.1 The analysis is to take account of the following:

- The effect of current on wave drift force.
- The effect of water depth on current forces, first order responses and wave drift.

5.3.2 For response analysis, anchor line properties are to be based on the total line diameter including corrosion allowance, *see* Table 10.8.1.

5.3.3 Weight and elasticity properties of anchor lines are to be obtained from chain or rope manufacturers. This information is to be documented and included in the submission.

5.4 Analysis

5.4.1 The following analyses, which may be combined, are to be carried out and submitted to LR:

- Hydrodynamic analysis of the floating unit.
- Motions analysis of the moored unit.
- Mooring analysis.

5.4.2 The following data has to be derived from the analyses:

- Steady force offsets, and tensions, from wind, current and wave drift.
- Wave frequency motions/accelerations.
- Low frequency offsets and tensions from 2nd order wave drift forces, and wind gust effects.

5.4.3 Time domain or frequency domain analysis methods can be applied. The basis for linearisation of the frequency domain analysis is to be documented.

5.4.4 For low frequency response analysis, the non-linear stiffness characteristics are to be satisfactorily represented. The amplitude of low frequency motion will be highly dependent on system damping from the following:

- Current.
- Wave drift.
- Viscous effects on the hull.
- Anchor lines and risers.
- Wind effects.

Thruster damping may also be applicable in relevant cases and the basis for the damping terms used in the analysis is to be documented and submitted.

5.4.5 Tensions due to low frequency, and wave frequency excitation can be computed separately. The effect of line dynamics is to be accounted for in wave frequency analysis. Low frequency tension can be based on quasi-static catenary response. Wave frequency dynamic line tension is to be computed at alternative low frequency offset positions, *see* 5.5.3.

5.5 Combination of low and high frequency components

5.5.1 Maximum design values for offset and tension are preferably to be derived from combined wave frequency and low frequency response analyses. The time domain simulations are to be of sufficient length to establish reasonable confidence levels in the predictions of maximum response. When squalls are considered, the approach for selecting the design values of tensions and offsets is to be agreed with LR.

5.5.2 The most probable maximum values for tension and offset can be determined from the distribution of peak loads. The statistical basis (Weibull, etc.) being applied to derive the probability distribution is to be documented and submitted.

5.5.3 Tensions and offset values can be combined as follows, when low frequency and wave frequency analyses are conducted separately:

(a) **Offset**:

$$X_{MAX} = X_{MEAN} + X_{LF\ sig} + X_{WF\ max}$$

or

$$X_{MAX} = X_{MEAN} + X_{LF\ max} + X_{WF\ sig}$$

whichever is the greater

where

X_{MAX} = maximum vessel offset
X_{MEAN} = mean vessel offset
$X_{LF\ sig}$ = significant low frequency offset
$X_{LF\ max}$ = maximum low frequency offset
$X_{WF\ sig}$ = significant wave frequency offset
$X_{WF\ max}$ = maximum wave frequency offset.

(b) **Tension**:

$$T_{MAX} = T_{MEAN} + T_{LF\ sig} + T_{WF\ max}$$

or

$$T_{MAX} = T_{MEAN} + T_{LF\ max} + T_{WF\ sig}$$

whichever is the greater

where

T_{MAX} = maximum tension
T_{MEAN} = tension at mean vessel offset
$T_{LF\ sig}$ = significant low frequency tension
$T_{LF\ max}$ = maximum low frequency tension
$T_{WF\ sig}$ = significant wave frequency tension computed at maximum low frequency offset position, $X_{LF\ max}$
$T_{WF\ max}$ = maximum wave frequency tension computed at significant low frequency offset position, $X_{LF\ sig}$.

5.5.4 Estimates of maximum design values can be based on the following:

(a) **Low frequency:**

$$X_{LF\,sig} = 2\sigma_{x\,LF}$$

$$X_{LF\,max} = \sigma_{x\,LF}\sqrt{2(\ln N_{LF})}$$

$$T_{LF\,sig} = 2\sigma_{T\,LF}$$

$$T_{LF\,max} = \sigma_{T\,LF}\sqrt{2(\ln N_{LF})}$$

where

$X_{LF\,sig}$ = significant low frequency offset
$X_{LF\,max}$ = maximum low frequency offset
$T_{LF\,sig}$ = significant low frequency tension
$T_{LF\,max}$ = maximum low frequency tension
σ_{xLF} = standard deviation of low frequency offset
σ_{TLF} = standard deviation of low frequency tension
N_{LF} = number of low frequency oscillations during short-term storm state (not less than 3 hour storm)
ln = $\log_e$
e = base of natural logarithms, 2,7183.

(b) **Wave frequency**:

$$X_{WF\,sig} = 2\sigma_{x\,WF}$$

$$X_{WF\,max} = \sigma_{x\,WF}\sqrt{2(\ln N_{WF})}$$

$$T_{WF\,sig} = 2\sigma_{T\,WF}$$

$$T_{WF\,max} = \sigma_{T\,WF}\sqrt{2(\ln N_{WF})}$$

where

$X_{WF\,sig}$ = significant wave frequency offset
$X_{WF\,max}$ = maximum wave frequency offset
$T_{WF\,sig}$ = significant wave frequency tension
$T_{WF\,max}$ = maximum wave frequency tension
$\sigma_{x\,WF}$ = standard deviation of wave frequency offset
$\sigma_{T\,WF}$ = standard deviation of wave frequency tension
N_{WF} = number of wave frequency oscillations during short-term storm state (not less than 3 hour storm)
ln = $\log_e$
e = base of natural logarithms, 2,7183.

■ *Section 6* Anchor lines

6.1 General

6.1.1 Anchor line length is to be sufficient to avoid uplift forces occurring at the anchor point for damaged condition loads, unless the anchor point is specially designed to accept a vertical component of loading.

6.1.2 An anchor line integrity monitoring system or device is to be provided for floating unit mooring systems, to detect line breakage and significant tension irregularities. This is not a requirement for offloading buoy systems.

6.1.3 Steel wire rope and chain requirements are defined in Sections 7 and 8 respectively.

6.1.4 In general, the break strength of the anchor line is not to be greater than the load bearing capacity of the connecting structure, *see also* Pt 4, Ch 6,1.

6.2 Factors of safety – Strength

6.2.1 Minimum factors of safety applicable to the wire rope and chain anchor lines of moored floating units are given in Table 10.6.1. For fibre ropes, *see* 9.2.2.

Table 10.6.1 Minimum factors of safety for anchor lines for floating offshore installations at a fixed location

Design case	Factor of safety, *see* Note 2	
	Intact	Damaged
Extreme storm, or maximum environment, with floating unit attached	1,67 *see* Note 1	1,25 *see* Note 1

NOTES
1. The factors of safety given in this Table are associated with the following conditions:
   (a) Arrangements being available to shut down production and/or transfer of oil or gas through risers in event of anchoring system failure.
   (b) The floating unit being located in an open sea area. Special consideration will be given to factors of safety when the unit is in close proximity to another installation, or is located near the shore.
2. Factor of safety = $\dfrac{\text{Anchor line minimum breaking strength}}{\text{Maximum tension}}$

   Anchor line minimum breaking strength basis to be documented.
   A reduction factor may require to be applied to the standard assigned minimum breaking strength of anchor line components in some cases (e.g., where component test database is small: for non-standard components), or where anchor line components are not new.

6.2.2 Factors of safety applicable to the wire rope and chain anchor lines of offshore loading buoys (CALMs, etc.) are given in Table 10.6.2. For fibre ropes, *see* 9.2.2.

6.2.3 **PM** notation (including **PM TA(1)**, **PM TA(2)** and **PM TA(3)**). Minimum factors of safety applicable to steel wire rope and chain anchor lines for mobile offshore units are given in Table 10.6.3.

6.2.4 **PMC** notation (including **PMC TA(1)**, **PMC TA(2)** and **PMC TA(3)**). Minimum factors of safety applicable to steel wire rope and chain anchor lines for mooring system for mobile offshore units analysed quasi-statically and dynamically are given in Tables 10.6.4 and 10.6.5 respectively.

6.3 Fatigue life

6.3.1 The fatigue life of the main components in the positional mooring system are to be verified. Calculations are to be submitted.

Table 10.6.2 Minimum factors of safety for anchor lines of offshore loading buoys

Design case	Factor of safety	
	Intact	Damaged
Extreme storm, or maximum storm condition with ship attached	1,85	1,35

NOTE
For special cases where allowable offset criteria for risers cannot be met in a Damaged Case (single line break) (e.g., in offshore loading buoy systems for shallow water), the Damaged Case can be omitted in design and an increased intact factor of safety applied. A minimum factor of safety of 2,3 is to be applied in this case.

Table 10.6.3 Factors of safety for PM notation

Design case	Description	Factors of safety for **PM** notation, *see* Note 1	
		Quasi-static analysis	Dynamic analysis
1	Operating (Intact)	2,7	2,3
2	Survival (Intact)	1,8	1,5
3	Operating (Single line failure)	1,8	1,5
4	Survival (Single line failure)	1,25	1,1

NOTES
1. The factors of safety given in this Table apply to units positioned at least 300 m from another unit.
2. The unit is to be positioned to avoid contact with another unit in any of the design cases.

Table 10.6.4 Factors of safety for PMC notation – Quasi-static analysis

Design case	Description	Factors of safety for **PMC** notation Quasi-static analysis, *see* Notes			
		Unit moored 50 m or less from other structures		Unit moored within 50 to 300 m from other structures	
		Critical line	Non-critical line	Critical line	Non-critical line
1	Operating (Intact)	3,0	2,7	3,0	2,7
2	Survival (Intact)	—	—	2,0	1,8
3	Operating (Single line failure)	2,0	1,8	2,0	1,8
4	Survival (Single line failure)	—	—	1,5	1,33

NOTES
1. *See also* 5.4.
2. The unit is to be positioned to avoid contact with another unit in any of the design cases.

6.3.2 Where applicable tension bending fatigue calculations at fairlead/stopper will need to be considered (e.g., for taut-leg mooring systems).

6.3.3 Fatigue life calculations for anchor lines can be carried out in accordance with a recognised Code, e.g., *API 2SK: Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures.*

6.3.4 Consideration will be given to the use of alternative methods, detailed proposals are to be submitted and agreed with LR.

6.3.5 The minimum factors of safety on the calculated fatigue lives for components of the mooring system are to comply with Table 6.5.2 in Pt 4, Ch 5.

Table 10.6.5 Factors of safety for PMC notation – Dynamic analysis

Design case	Description	Factors of safety for **PMC** notation Dynamic analysis, *see* Notes			
		Unit moored 50 m or less from other structures		Unit moored within 50 to 300 m from other structures	
		Critical line	Non-critical line	Critical line	Non-critical line
1	Operating (Intact)	2,5	2,3	2,5	2,3
2	Survival (Intact)	—	—	1,65	1,5
3	Operating (Single line failure)	1,65	1,5	1,65	1,5
4	Survival (Single line failure)	—	—	1,35	1,2

NOTES
1. *See also* 5.4.
2. The unit is to be positioned to avoid contact with another unit in any of the design cases.

■ *Section 7* **Wire ropes**

7.1 General

7.1.1 This Section applies to steel wire ropes for offshore positional mooring systems.

7.1.2 Wire ropes and associated fittings are to be of an approved design.

7.2 Rope construction

7.2.1 When selecting a rope construction the following considerations apply:
- Required service life.
- Position in catenary.
- Axial stiffness properties of rope.
- Bending over sheaves, etc.
- Characteristic torsional properties of rope construction.

7.2.2 Various rope constructions can be accepted for long-term mooring applications. These include:
- spiral strand.
- locked coil.
- six-strand.

Other constructions can be considered.

7.3 Design verification

7.3.1 The design of wire rope and associated fittings is to be verified. The following information will be required for appraisal and information:
- Plans of rope, socket and other fittings.
- Materials.
- Design specification.
- Purchaser's specification.
- Codes and Standards applied.
- Calculations for the strength and fatigue of rope, socket, fittings, and their corrosion protection.
- Torsional stiffness data.

7.3.2 Data from prototype rope tests is to be made available as required.

7.3.3 Fatigue life calculations for steel wire ropes can be carried out in accordance with a recommended Code, e.g., *API RP 2SK: Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures.* Rope bending fatigue effects are to be included where relevant.

7.3.4 The minimum factors of safety on the calculated fatigue lives of wire rope and fittings are to comply with Table 6.5.2 in Pt 4, Ch 5.

7.3.5 The rope termination including the socket is to be designed to withstand a load of not less than the minimum breaking strength of the attached wire rope.

7.4 Materials

7.4.1 Steel wire used for rope manufacture is to be manufactured in accordance with a recognised National Standard:

(a) The steel is to be of homogeneous quality, consistent strength, and free from visual defects likely to impair the performance of the rope.

(b) The minimum tensile strength of the wire is to be the tensile strength ordered. The maximum tensile strength is not to exceed the specified minimum strength by more than 230 N/mm^2. The tensile strength should normally be within the range 1420 to 1770 N/mm^2.

7.4.2 The material used in the manufacture of sockets is to comply with the following requirements:

(a) **Cast sockets**:
- Castings are to be manufactured and tested generally in accordance with Chapter 4 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).
- As a supplement to Chapter 4 of the Rules for Materials, impact tests are to be carried out at a test temperature of minus 20°C, to satisfy a minimum average energy requirement of 40J, with no more than one individual result from each three test specimens being less than 70 per cent of the required minimum average. Increased material toughness may be required in specific cases.
- Alternative casting standards to Chapter 4 of the Rules for Materials complying with recognised national or proprietary specifications may be accepted, *see also* Ch 4,1.1.3 of the Rules for Materials.

(b) **Fabricated sockets**:
- Plate material to be Grade D or DH quality in accordance with Chapter 3 of the Rules for Materials. Increased material toughness may be required in some cases.
- Plate with through-thickness properties will generally be required, in accordance with Ch 3,8 of the Rules for Materials.

(c) **Socket pins**:
- Socket pins may be cast or forged. Where cast, material requirements are to comply with (a) above. Forged socket pins are to be manufactured in accordance with Chapter 5 of the Rules for Materials.
- As a supplement to Chapter 5 of the Rules for Materials, impact tests are to be carried out at a test temperature of minus 20°C, to satisfy a minimum average energy requirement of 40J, with no more than one individual result from each three test specimens being less than 70 per cent of the required minimum average. Increased material toughness may be required in specific cases.
- Alternative standards to Chapter 5 of the Rules for Materials, complying with recognised national or proprietary specifications may be accepted, *see also* Ch 5,1.1.3 of the Rules for Materials.

7.5 Corrosion protection

7.5.1 Wire ropes are to be protected against corrosion. The corrosion protection will normally consist of galvanising or other sacrificial coating of individual wires. Filler wires of zinc or other suitable sacrificial material can be incorporated in the outer layers of the rope, as an addition to, but not in place of, galvanising of individual wires.

7.5.2 Galvanising is to meet the following minimum standards:

(a) Zinc:
- BS EN 1179.

(b) Zinc weight:
- ASTM A 603 Table 5, Class A (spiral strand and locked coil).
- ISO 2232, Quality B (six-strand ropes).

(c) Alternative recognised Codes or Standards providing acceptable equivalence will be considered.

7.5.3 Sockets are to be protected against corrosion by sacrificial anodes or acceptable equivalent.

7.5.4 Suitable arrangements are to be made to insulate the corrosion protected rope/socket assembly from adjacent non-protected elements in the system.

7.5.5 Polyethylene sheathing can also be used on appropriate rope constructions, as an addition to, but not normally as an alternative to, galvanising:

(a) Where sheathing is intended to be fitted, the specification is to be submitted. ASTM D 1248 is an acceptable specification for medium or high density polyethylene sheathing.

(b) A continuous strip of contrasting colour is to be incorporated into the sheathing to aid monitoring for twist.

7.6 Manufacture and testing

7.6.1 Steel wire ropes are to be manufactured in accordance with the design standards and procedures and at a works approved by LR. Ropes and fittings will be subject to LR survey during manufacture and testing.

7.6.2 A certified ISO 9001/9002 Quality System is to be in place and a quality plan is to be produced and agreed with LR's Surveyors.

7.6.3 Where sheathing is specified, it is to be carried out in accordance with the Quality Plan.

7.6.4 Cast sockets are to be manufactured and tested in accordance with the requirements of 7.4.2(a).

7.6.5 The following minimum requirements for the non-destructive testing of cast sockets are applicable:

(a) **Ultrasonics**: All areas of all sockets and pins.

(b) **Radiography:** Critical areas of first, last, and one intermediate socket selected by the LR Surveyor to be examined. Critical areas to be identified on design drawings, and these to be included in the design submission for verification.

(c) **Magnetic Particle Inspection (MPI)**: 100 per cent of all sockets and pins.

(d) **Visual:** 100 per cent of all sockets and pins.

7.6.6 The material of plate fabricated sockets is to comply with 7.4.2(b) and welding and NDE to be in accordance with Pt 4, Ch 8. Post-weld heat treatment to be carried out for thicknesses exceeding 65 mm.

7.6.7 Tests are to be carried out on individual wires for the following:

- Tensile strength and elongation.
- Torsion.
- Reverse bend.
- Zinc coating; mass, uniformity and adhesion.

Tests are to be carried out in accordance with recognised National Standards such as ISO 2232, and ASTM A603, as appropriate.

7.6.8 Rope production samples are to be tested for the following:

- Modulus.
- Minimum breaking strength.

7.6.9 The tests required by 7.6.8 are to be as follows:

(a) The modulus test is to be carried out on one finished rope sample taken from the first production length. Production sockets need not be fitted for this particular test. Load/extension characteristics and permanent stretch are to be determined and documented. Acceptance criteria for permanent stretch is to be as follows:
   - Maximum of 0,4 per cent for spiral strand and locked coil ropes.
   - Maximum of 0,8 per cent for six-strand ropes.

   The modulus of elasticity is to be calculated and documented. The basis for the calculated value (cross-sectional metallic area, or area of circle enclosing the rope) is to be clearly stated.

(b) Breaking load test is to be carried out on one sample taken from each manufactured length.
   - Where the rope design, the machine, and the machine settings are identical, consideration can be given to a reduction in the number of tests. As a minimum, breaking load tests are to be carried out on a sample taken from each of the first manufactured length, and one other length, selected by LR Surveyors.
   - Tests are to be carried out in accordance with a recognised National Standard such as DIN 51201.
   - One of the rope samples is to be fitted at one end with a socket taken from the project production batch, and socketed in accordance with approved procedures. Where more than one socket design type is involved, a further assembly is to be tested for each different type of socket.
   - The rope sample and the production socket is to withstand the specified minimum breaking load. The socket pin is to be able to be removed after the test, and replaced, without the application of undue force.
   - NDE to be carried out on the socket following testing (100 per cent visual and 100 per cent MPI).

7.7 Identification

7.7.1 Each wire rope assembly is to be marked at each end with the letters LR and the Certificate Number.

7.8 Certification

7.8.1 A certificate is to be issued for each rope assembly by LR. The following is to be included in the Certificate:

- Purchaser's name and order number.
- Description of order, including wire rope diameter and construction.
- Tested minimum breaking load.
- Design Appraisal Document Number.
- Socket inspection certificate references.
- Individual wire certificate references.
- Sheathing report references.

■ *Section 8* Chains

8.1 Chain grades

8.1.1 Chains to be offshore Grades R3, R3S, or R4 and are to comply with Ch 10,3 and Ch 10,4 of the Rules for Materials, as applicable. Acceptance of other grades will be subject to special consideration.

8.2 Corrosion and wear

8.2.1 A size margin over and above the minimum chain size required to satisfy Rule factor of safety requirements is to be included to allow for the corrosion and wear which can occur over the intended service life of the anchor chain or associated component. The minimum margins shown in Table 10.8.1 are recommended.

Table 10.8.1 Chain size corrosion and wear margins

Region of anchor chain	Margin (mm per year service life, on chain diameter)
Splash zone	0,3
Catenary	0,2
Touch down zone and sea bed	0,4
NOTE Additional margins greater than those indicated in the Table may be required where chains are subjected to high wear rates.	

■ *Section 9* Provisional requirements for fibre ropes

9.1 General

9.1.1 This Section gives provisional requirements for fibre ropes used in positional mooring systems. The requirements apply to fibre ropes incorporated as follows:

(a) **Catenary mooring system**:
- Fibre rope insert lines, these being confined to the suspended part of the catenary system. Chain or wire rope will be fitted in parts of the anchor leg subject to contact with sea bed or floating unit.

(b) **Taut-leg moorings**:
- In this case, fibre rope will form the majority of the anchor leg's length. System compliancy will come from the inherent extensibility of the fibre rope. Chain will be fitted at upper and lower parts of the taut leg, where hard contact can occur.
- Special consideration will be given to other types of fibre rope mooring application.

9.2 Design aspects

9.2.1 Fibre ropes and associated fittings are to be of an approved design. The following information to be submitted:

(a) Specifications:
- Rope purchaser's specification.
- Rope design specification.
- Rope manufacturing and testing specification.

(b) Plans:
- Rope, spool piece and other fittings.

(c) Calculations:
- Strength and fatigue of rope and fittings.

(d) Rope particulars:
- Fibre type.
- Diameter of rope.
- Length at specified tension.
- Construction.
- Weight in air and water.
- Sheathing type.
- Terminations.
- Bend limiters.

(e) Rope properties:
- Minimum breaking strength.
- Mean breaking load of rope and coefficient of variation, from tests.
- Axial stiffness values (to cover upper and lower bounds of stiffness).
- Fatigue data (tension-tension and compression).
- Creep.
- Hysteresis.
- Torque/twist.
- Resistance to chemical attack in an offshore environment.
- Long-term degradation.

9.2.2 Factors of safety for fibre rope anchor line elements are to be a minimum of 20 per cent higher than the levels given in Section 6 for chain and wire rope materials.

$$\text{Factor of Safety} = \frac{\text{Minimum breaking strength}}{\text{Maximum tension}}$$

A reduction factor will require to be applied to the standard designated Minimum Breaking Strength, where the test database for the rope type is statistically small.

9.2.3 The fibre rope section of an anchor leg is not to touch the sea bed in any intact or damaged condition.

9.2.4 Fibre ropes are to be kept sufficiently far below the waterline, and below the connection point on the unit, to avoid any possibility of contact damage.

9.3 Manufacture

9.3.1 Fibre ropes are to be manufactured at a works approved by LR.

9.3.2 Ropes and fittings will be subject to LR survey during manufacture and testing.

9.3.3 A certified ISO 9001/9002 Quality System is to be in place and a quality plan is to be produced and agreed with LR Surveyors.

9.3.4 The ropes and fittings are to be manufactured in accordance with the approved design, standards and procedures.

9.3.5 *See also* requirement of Ch 10,7 of the Rules for Materials.

Section 10
Anchor points

10.1 Drag embedment anchors – Structural aspects

10.1.1 This sub-Section, and 10.2, apply to drag embedment anchors of high holding power type. Proposals for the use of other anchor types will be specially considered.

10.1.2 Anchors are to be of an approved type.

10.1.3 Material selection for drag embedment anchors are, generally, to be in accordance with Pt 4, Ch 2,4, taking the structural category as ‘Primary’.

10.1.4 Supporting calculations to verify the structural strength of the anchor for design service loads and for proof test loads are to be submitted.

10.1.5 The anchors are to be manufactured in accordance with the requirements of Chapter 10 of the Rules for Materials.

10.1.6 Anchors are to be subject to proof test loading in the manner laid down in the Rules. The level of proof test loading for positional mooring anchors is 50 per cent of the minimum rated breaking strength of the attached anchor line.

10.1.7 Proof load testing of large fabricated anchors (in excess of 15 tonnes mass) may be waived for classification, subject to the following:

(a) Structural strength of anchor type being verified by finite element analysis procedure.

(b) All main structural welds being subject to non-destructive examination as follows at manufacture:
- 100 per cent visual.
- 100 per cent MPI.
- 100 per cent UT/radiographic, for full penetration welds.

10.1.8 Notwithstanding the above, attention is drawn to the separate requirement of some National Authorities for proof load testing of anchors.

10.2 Drag embedment anchors – Holding capacity

10.2.1 The requirements of 10.1 are also to be considered, in addition to this sub-Section.

10.2.2 The following information is to be submitted:
- Data, calculations and analysis supporting the selection of anchor.
- Anchor details.
- Proposed test loading at installation.

and in addition for floating offshore installations at a fixed location:
- Soils data for the anchor locations.

10.2.3 Factors of safety for anchor holding capacity for floating offshore installations at a fixed location are not to be less than the values given in Table 10.10.1. Anchors for positional mooring of mobile offshore units are to be sufficient in number and holding capacity for the intended service. It is the Owner's/Operator's responsibility to ensure adequate anchor holding capacity for each location or holding ground.

Table 10.10.1 Factors of safety for anchor holding capacity for floating offshore installations at a fixed location

Design case	Anchor load case	Factor of safety
Intact	Static load, *see* Note 1	2,0
Intact	Dynamic load, *see* Note 1	1,5
Damaged	Dynamic load	1,15

NOTES
1. Static load refers to steady plus low frequency load components. Dynamic load refers to static plus wave frequency components of loading.
2. Increased factors of safety will require to be applied where the data supporting the anchor selection is not considered adequate in a particular case.
3. Where the use of vertically loaded anchors (VLAs) is proposed, for soft soil areas, special consideration will be given to required factors of safety.

10.2.4 An acceptable basis for drag anchor design for floating offshore installations at a fixed location is contained in Ch 14,4.

10.2.5 All anchors will require to be test loaded at installation, to the satisfaction of LR Surveyors. The installation test load is to be agreed, but is normally not to be less than 80 per cent of the maximum Intact Load. The test load is not, however, to exceed 50 per cent of the minimum breaking strength of the anchor line. The test load is to be held for a minimum of 20 minutes.

10.3 Anchor piles

10.3.1 This sub-Section applies to anchor piles which are either driven or drilled and grouted into the sea bed to provide resistance to axial, lateral and torsional loading. Piles installed by vibrating hammers are not recommended where axial loading is significant.

10.3.2 Anchor piles are characterised by being relatively long and slender and having a length to diameter or width ratio generally greater than 10.

10.3.3 The anchor pile design is to be approved by LR.

10.3.4 The anchor pile is to be designed to provide sufficient ultimate capacity to resist the maximum applied axial, lateral and torsional loads with appropriate factors of safety based on a working stress design approach.

10.3.5 Anchor piles designed to resist the maximum applied vertical, lateral and torsional loads with appropriate loads and resistance coefficient based on a load and resistance factor design approach are to be specially considered. In addition to performing ultimate limit state (ULS) analyses for anchor pile stability, serviceability limit state (SLS) analyses should also be performed to assess pile deflection and rotation.

10.3.6 Table 10.10.2 defines the design case and factors of safety to be used for anchor piles for a catenary mooring system. Table 10.10.2 does not apply to axial capacity of piles installed by vibrating hammers.

Table 10.10.2 Minimum factors of safety for anchor piles for a catenary mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,0	2,0
Intact	Dynamic load, *see* Note 2	1,5	1,5
Damaged	Dynamic load	1,5	1,5

NOTES
1. Static load refers to steady plus low frequency components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

10.3.7 Table 10.10.3 defines the design case and factors of safety to be used for anchor piles for a taut-leg mooring system. Table 10.10.3 does not apply to axial capacity of piles installed by vibrating hammers.

Table 10.10.3 Minimum factors of safety for anchor piles for a taut-leg mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,7	2,0
Intact	Dynamic load *see* Note 2	2,0	1,5
Damaged	Dynamic load	2,0	1,5

NOTES
1. Static load refers to steady plus low frequency components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

10.3.8 The factors of safety given in Table 10.10.3 are applicable to anchor pile groups for taut-leg mooring systems. Individual anchor piles within a group are to achieve a minimum factor of safety of 1,5.

10.3.9 Anchor pile analysis is generally performed using a beam-column finite element analysis with the soil resistance modelled using non-linear axial and lateral load-deflection response curves. The axial and lateral pile behaviour is considered to be uncoupled except for the effect of axial load on pile bending stresses, p-y effect. For anchor pile analysis performed using a continuum finite element model of the pile and soil, sufficient load cases should be analysed to investigate the effects of axial, lateral and combined axial and lateral loading on pile stability considering the factors of safety given in Tables 10.10.2 and 10.10.3.

10.3.10 The possible variation in inclination of the applied loading to the anchor pile is to be taken into account.

10.3.11 Consideration is to be given to the effects of cyclic loading on anchor pile capacity.

10.3.12 For anchor piles subjected to permanent tension loads, consideration is to be given to long-term changes to soil stresses around the anchor piles and upward creep.

10.3.13 Consideration could be given to performing special tests, such as centrifuge model tests, to provide a better understanding of anchor pile behaviour.

10.3.14 The anchor pile response under lateral and torsional loading is to be determined to ensure that deflections and rotations remain within tolerable limits. The effect on capacity of scouring of sea bed soils around the anchor pile is to be considered, unless the pile head is to be installed below sea bed level.

10.3.15 Consideration is to be given to the possible formation of a posthole at the pile head and its effect on capacity.

10.3.16 No account is to be taken of soil suction at the pile tip or the effect of rate of loading.

10.3.17 Analysis of the anchor pile/soil interaction response is to take into account the non-linear stress/strain behaviour of the foundation soils and the stress history and cyclic loading effects on soil resistance. Allowance is to be made for the response of different soil types.

10.3.18 An acceptable basis for anchor pile design is contained in Ch 14,6.

10.3.19 The anchor pile is to have sufficient strength to account for axial and bending stresses due to extreme, operating and installation loading conditions in accordance with Ch 14,6.

10.3.20 The connection between the anchor line and anchor pile is to be suitably designed in accordance with Pt 4, Ch 5,1. Where necessary, a detailed finite element stress analysis shall be carried out.

10.3.21 A driveability study should be performed for driven anchor piles to assess the driving stresses in both the anchor pile and connection between the anchor line and pile.

10.3.22 A fatigue damage assessment should be performed for both the anchor pile and connection between the anchor line and pile, taking into account stress ranges due to environmental loading and pile driving, where appropriate. Particular attention should be given to any stiffening arrangement of the connection between the anchor line and pile. For certain soil conditions, stiffening arrangements internal to the pile can have a significant influence on the number of hammer blows required to achieve design pile penetration during driving and the fatigue damage.

10.3.23 Consideration is to be given to the anchor pile installation tolerances on verticality and orientation when designing the connection between the anchor line and anchor pile.

10.3.24 The connection between the anchor line and anchor pile is to be designed so as to minimise disturbance to the sea bed soils during pile installation, which could reduce the axial and lateral resistance provided by the anchor pile. Reduction in anchor pile capacity is to be taken into account.

10.3.25 Details of the proposed method of anchor pile and anchor line installation are to be submitted. Consideration is to be given to the tolerances associated with anchor pile verticality and orientation.

10.3.26 Requirements for anchor pile installation are contained in Ch 14,6.

10.3.27 Anchor piles are not required to be test loaded at installation. However, for catenary mooring systems, pre-loading of the anchor line is to be carried out to ensure its alignment through the sea bed soil.

10.3.28 For taut-leg mooring systems, consideration is to be given to the provision of a monitoring system for the measurement of long-term vertical movements of the anchor piles relative to the surrounding soil.

10.4 Suction anchor piles

10.4.1 This sub-Section applies to anchor piles which are installed by suction to achieve the required penetration into the sea bed to provide resistance to axial, lateral and torsional loading. Suction is applied by creating a reduced water pressure within the pile compared to the external ambient water pressure. Suction anchor piles can be retrieved from the sea bed by reversing the suction process.

10.4.2 Suction anchor piles are characterised by having a large diameter and a length to diameter ratio generally less than eight and are essentially caisson-type foundations if it is less than three.

10.4.3 The suction anchor pile design is to be approved by LR.

10.4.4 The suction anchor pile is to be designed to provide sufficient ultimate capacity to resist the maximum applied axial, lateral and torsional loads with appropriate factors of safety based on a working stress design approach.

10.4.5 Suction anchor piles designed to resist the maximum applied vertical, lateral and torsional loads with appropriate load and resistance coefficients based on a load and resistance factor design approach are to be specially considered. In addition to performing ultimate limit state (ULS) analyses for suction anchor pile stability, serviceability limit state (SLS) analyses should also be performed to assess pile deflection and rotation.

10.4.6 Table 10.10.4 defines the design case and factors of safety to be used for suction anchor piles for a catenary mooring system.

Table 10.10.4 Minimum factors of safety for suction anchor piles for a catenary mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,0	2,0
Intact	Dynamic load, *see* Note 2	1,5	1,5
Damaged	Dynamic load	1,3	1,3

NOTES
1. Static load refers to steady plus low frequency components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

10.4.7 Table 10.10.5 defines the design case and factors of safety to be used for suction anchor piles for a taut-leg mooring system.

Table 10.10.5 Minimum factors of safety for suction anchor piles for a taut-leg mooring system

Design case	Anchor load case	Factor of safety	
		Axial loading	Lateral loading
Intact	Static load, *see* Note 1	2,7	2,0
Intact	Dynamic load, *see* Note 2	2,0	1,5
Damaged	Dynamic load	2,0	1,3

NOTES
1. Static load refers to steady plus low frequency components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

10.4.8 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of suction anchor piles. The installation tolerances are to be considered when assessing failure modes for the soil.

10.4.9 Suction anchor pile analysis is generally performed using either a continuum finite element model or a limit plasticity model of the pile and soil in order to assess appropriate failure modes. Sufficient load cases should be analysed to investigate the effects of axial, lateral and combined axial and lateral loading on suction anchor pile stability considering the factors of safety given in Tables 10.10.4 and 10.10.5.

10.4.10 The possible variation in inclination of the applied loading to the suction anchor pile is to be taken into account.

10.4.11 Consideration is to be given to the effects of cyclic loading on suction anchor pile capacity.

10.4.12 For suction anchor piles subjected to permanent tension loads, consideration is to be given to long-term changes to soil stresses around the suction anchor pile and upward creep.

10.4.13 Consideration is to be given to performing special tests, such as centrifuge model tests, to provide a better understanding of suction anchor pile behaviour.

10.4.14 The suction anchor pile response under lateral and torsional loading is to be determined to ensure that deflections and rotations remain within tolerable limits. The effect on capacity of scouring of sea bed soils around the anchor piles is to be considered.

10.4.15 Consideration is to be given to the possible formation of a posthole at the pile head and its effect on capacity.

10.4.16 No account is to be taken of soil suction at the pile tip or the effect of rate of loading, unless the suction anchor pile is provided with a cap and suction can be justified based on rate of loading and soil permeability.

10.4.17 Analysis of the suction anchor pile/soil interaction response is to take into account the non-linear stress/strain behaviour of the foundation soils and the stress history and cyclic loading effects on soil resistance. Allowance is to be made for the response of different soil types.

10.4.18 An acceptable basis for suction anchor pile design is contained in Ch 14,6.

10.4.19 The suction anchor pile is to have sufficient strength to account for the stresses due to extreme operating and installation loading conditions in accordance with Chapter 14 and Part 10 (for ship units). Where necessary, a detailed finite element stress analysis is to be carried out.

10.4.20 The connection between the anchor line and suction anchor pile is to be suitably designed in accordance with Pt 4, Ch 6,1. Where necessary, a detailed finite element stress analysis is to be carried out.

10.4.21 A fatigue damage assessment should be performed for both the suction anchor pile and connection between the anchor line and suction pile taking into account stress ranges due to environmental loading. Particular attention should be given to any stiffening arrangement of the connection between the anchor line and pile.

10.4.22 Consideration is to be given to the suction anchor pile installation tolerances on verticality and orientation when designing the connection between the anchor line and suction anchor pile.

10.4.23 The connection between the anchor line and suction anchor pile is to be designed so as to minimise disturbance to the sea bed soils during pile installation, which could reduce the axial and lateral resistance provided by the suction anchor pile. Reduction in suction anchor pile capacity is to be taken into account.

10.4.24 Details of the proposed method of suction anchor pile and anchor line installation are to be submitted. Consideration is to be given to the tolerances associated with suction anchor pile verticality and orientation and also to the internal soil heave.

10.4.25 Requirements for suction anchor pile installation are contained in Ch 14,6.

10.4.26 Suction anchor piles are not required to be test loaded at installation. However, for catenary mooring systems, preloading of the anchor line is to be carried out to ensure its alignment through the sea bed soil.

10.4.27 For taut-leg mooring systems, consideration could be given to the provision of a monitoring system for the measurement of long-term vertical movements of the suction anchor piles relative to the surrounding soil.

10.5 Gravity anchors

10.5.1 This sub-Section applies to gravity frame or block anchors, which rely on their mass to provide resistance to vertical, lateral and torsional loading. Gravity anchors may be provided with skirts which penetrate the sea bed to provide increased lateral resistance.

10.5.2 The gravity anchor design is to be approved by LR.

10.5.3 The gravity anchor is to be designed to resist the maximum applied vertical, lateral and torsional loads with appropriate load and material coefficients based on a load and resistance factor design approach.

10.5.4 A material coefficient for soil of 1,25 is to be applied to the design shear strength, tangent of the angle of internal friction of the soil and tangent of the angle of interface friction between the soil and gravity anchor.

10.5.5 Appropriate load coefficients will be specially considered for particular applications for catenary and taut-leg mooring systems.

10.5.6 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of gravity anchors. The installation tolerances are to be taken into account when assessing failure modes for the soil.

10.5.7 The possible variation in inclination of the applied loading to the gravity anchor is to be taken into account.

10.5.8 Consideration is to be given to the effects of cyclic loading on gravity anchor capacity.

10.5.9 Consideration is to be given to performing special tests, such as centrifuge model tests, to provide a better understanding of gravity anchor behaviour.

10.5.10 The gravity anchor response under vertical, lateral and torsional loading is to be determined to ensure that deflections and rotations remain within tolerable limits.

10.5.11 Consideration is to be given to the possible scouring of sea bed soils around the gravity anchor and its effect on capacity.

10.5.12 No account is to be taken of soil suction or the effect of rate of loading.

10.5.13 Analysis of the gravity anchor/soil interaction response is to take into account the non-linear stress/strain behaviour of the foundation soils and the stress history and cyclic loading effects on soil resistance. Allowance is to be made for the response of different soil types.

10.5.14 An acceptable basis for gravity anchor design is contained in Ch 14,7.

10.5.15 The gravity anchor is to have sufficient strength to account for the stresses due to survival, operating and installation loading conditions in accordance with Ch 14,7 and Part 10 (for ship units). Where necessary, a detailed finite element stress analysis is to be carried out. Reinforced concrete gravity anchors are to be specially considered.

10.5.16 The connection between the anchor line and gravity anchor is to be suitably designed in accordance with Pt 4, Ch 6,1. Where necessary, a detailed finite element stress analysis is to be carried out.

10.5.17 A fatigue damage assessment should be performed for the connection between the anchor line and gravity anchor, taking into account stress ranges due to environmental loading. Particular attention should be given to any stiffening arrangement of the connection between the anchor line and gravity anchor.

10.5.18 Consideration is to be given to the gravity anchor installation tolerances on inclination and orientation when designing the connection between the anchor line and gravity anchor.

10.5.19 Details of the proposed method of gravity anchor and anchor line installation are to be submitted. Consideration is to be given to the tolerances associated with gravity anchor inclination and orientation and skirt penetration, if applicable.

10.5.20 Requirements for gravity anchor installation are contained in Chapter 14,7.

10.5.21 Gravity anchors are not required to be test loaded at installation. However, for catenary mooring systems, pre-loading of the anchor line is to be carried out to ensure its alignment along the sea bed.

■ *Section 11* Fairleads and cable stoppers

11.1 General requirements

11.1.1 Fairleads and stoppers are to be designed to permit free movement of the anchor line in all mooring configurations and designed to prevent excessive bending and wear of the anchor lines. The hardness of fairleads and chain stoppers where in contact with the anchor line should be softer than the anchor line. In general, the anchor line should not be in contact with any welds but where this is not possible the welds are to be ground flush and are to be softer than the anchor line.

11.1.2 The minimum operating range of the fairlead to be considered in conjunction with the design load is shown in Fig. 10.11.1.

11.1.3 Fairleads and stoppers and their supporting structures are to be designed for a load equivalent to either mooring line maximum design load when defined or the rated minimum break strength of the anchor line, but *see also* 11.1.8 and Pt 4, Ch 6,1.1.6.

11.1.4 The maximum permissible stresses for the design criteria given in this sub-Section are to be in accordance with Pt 4, Ch 5,2.1.1(c).

11.1.5 Materials and steel grades are generally to comply with the requirements given in Pt 4, Ch 2 for primary structures.

11.1.6 Chain cable fairleads are to have a minimum of five pockets.

11.1.7 Wire rope fairleads are generally to have a minimum diameter of 16 times the wire rope diameter.

11.1.8 Special consideration will be given to permissible stresses where the chain is of downgraded quality. There have been cases of closing plates on the fairlead shaft coming loose due to corrosion of the threads of the securing bolts, resulting in serious damage to the fairlead arrangements and the complete jamming of the fairlead and chain. Consequently, the securing bolts should also be checked to ensure that the bolt material does not corrode preferentially should the sacrificial anode system fail to function in way of the fairlead.

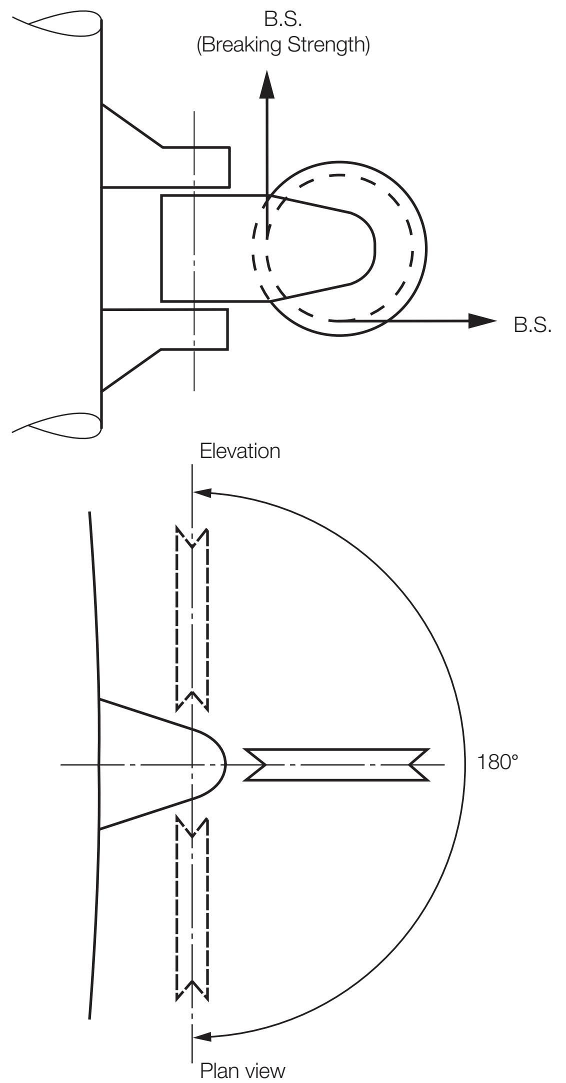


Fig. 10.11.1
Minimum operating range of fairlead

■ *Section 12*
Anchor winches and windlasses

12.1 General

12.1.1 This Section applies to winches and windlasses designed actively to control anchor line tensions in-service, or to release anchor lines in an emergency.

12.1.2 Special consideration will be given to requirements for winches and windlasses for passive mooring systems, or permanent mooring systems.

12.1.3 Machinery items are to be constructed to recognised design Codes and Standards. The relevant requirements of Part 5 may be used as guidance for small and simple equipment, but for larger and more complex designs, special analysis techniques such as finite element methods (or equivalent) are considered to be more appropriate.

12.1.4 Machinery items are to be installed and tested in accordance with the relevant requirements of Part 5. For electrical and control equipment, *see* Section 13.

12.2 Materials

12.2.1 Materials are to comply with the Rules for Materials. Alternatively, materials which comply with national or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials, or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

12.2.2 For the selection of material grades, individual components of anchor winches and windlasses are to be categorised as primary or secondary.

12.2.3 Components where the failure would result in the loss of a primary function of the winch or windlass are considered to be ‘primary components’, *see also* 12.2.5.

12.2.4 All other components where the failure would not result in the loss of a primary function of the winch or windlass are to be categorised as ‘secondary components’.

12.2.5 Primary components which are designed with an adequate degree of redundancy in their operation will be specially considered and may be categorised as secondary.

12.2.6 Material grades for all components are in general related to the thickness of the material, the structural category and the minimum design air temperature and are to be selected to provide adequate notch toughness.

12.2.7 Material grades for welded plate components are in general to comply with Pt 4, Ch 2,4. For thicker plates and/or lower design temperature the steel grades will be specially considered.

12.2.8 Material grades for components which are not subject to welding will be specially considered.

12.2.9 Castings and forgings are to comply with Chapters 4 and 5 of the Rules for Materials respectively and the requirements for notch toughness in relation to the design air temperature will be specially considered.

12.2.10 Non-ductile materials are not to be used for torque transmitting items or for those elements subject to tensile/bending stresses.

12.2.11 Spheroid graphite iron castings are to comply with Ch 7,3 of the Rules for Materials, Grades 370/17 or 400/12, or to an equivalent National Standard.

12.2.12 The use of grey iron castings will be subject to special consideration. Where approved, they are to comply with the requirements of Ch 7,2 of the Rules for Materials. This material is not to be used for gear components.

12.2.13 Brake lining materials are to be compatible with operating environmental conditions.

12.3 Brakes

12.3.1 Each anchor winch or windlass is required to have one primary braking system and one secondary braking system. The two systems are to operate independently. The requirements of 12.5 are to be complied with.

12.3.2 The braking action of the motor unit may be used for secondary braking purposes where the design is suitable.

12.3.3 A residual braking force of at least 50 per cent of the maximum braking force required by 12.5.1 is to be immediately available and automatically applied in the event of a power failure.

12.4 Stoppers

12.4.1 If the winch motor is to be used as a secondary brake then a stopper is to be provided to take the anchor line load during maintenance of the primary brake.

12.4.2 The stopper may be one of two different types: a pawl stopper fitted at the cable lifter/drum shaft, or a stopper acting directly on the anchor line.

12.4.3 Where the stopper acts directly on the cable, its design is to be such that the cable will not be damaged by the stopper at a load equivalent to the rated breaking strength of the cable.

12.4.4 *See also* 13.4.11 and 13.4.12, for stopper control station requirements, and 13.4.6, for emergency release of stoppers.

12.5 Winch/windlass performance

12.5.1 The primary brake is required to hold a static load equal to the minimum break strength of the anchor line (at the intended outer working layer of wire rope on storage drum winches). The static load capacity of the primary brake can be reduced to 80 per cent of that value when a stopper capable of holding 100 per cent of the breaking strength of the line is fitted.

12.5.2 The secondary brake is required to hold a static load equal to 50 per cent of the minimum breaking strength of the anchor line.

12.5.3 For passive or permanent positional mooring systems the primary brake is required to hold a static load equal to 150 per cent of the winch/windlass capacity, when isolated from operational/survival mooring line loads using a stopper. A secondary brake is not required in this case.

12.5.4 The anchor winch or windlass is to have adequate dynamic braking capability. The two brake systems in joint operation are to be capable of fully controlling without overheating, the anchor lines during:

- all anchor handling operations;
- adjustment of anchor line tensions. (This is particularly relevant where the mooring system has been designed and sized on the basis of active adjustment of anchor lines in extreme conditions, to minimise line tensions.)

12.5.5 *See also* 13.4 for control of winches, windlasses, stoppers and pawls, for brake fail-safe requirements and standby power for operation of brakes and release of stoppers in the event of a failure of normal power supply.

12.5.6 Means are to be provided to enable the anchor lines to be released from the unit after loss of main power.

12.5.7 The pulling force of the winches or windlasses is to be sufficient to carry out anchor pre-loading on location, to the necessary level. A minimum low-speed pull equal to 40 per cent of the anchor line breaking strength is recommended.

12.6 Strength

12.6.1 Design load cases for the winch or windlass assembly and the stopper, when fitted, are given in Table 10.12.1. The associated maximum allowable stresses are to be based on the factors of safety given in Table 10.12.2.

Table 10.12.1 Design load cases

Load case	Condition	Anchor line load percentage of break strength
1	Winch braked	100%, *see* Note
2	Stopper engaged	100%
3	Winch pulling	40% or specified duty pull if greater
NOTE Where a stopper is fitted, the anchor line load in Case 1 may be taken as the brake slipping load, but is not to be less than 80% of the break strength of the anchor line.		

12.7 Testing

12.7.1 Tests are to be carried out at the manufacturer's works in the presence of the Surveyor, on at least one of the winches or windlasses out of the total outfit for the unit. The tests to be carried out are given in Table 10.12.3. Alternatively, where a prototype winch has been suitably tested, consideration will be given to the acceptance of these results.

12.7.2 The residual braking capability is to be verified in accordance with 12.5.4.

Table 10.12.2 Load case factors of safety

Stress	Load case	
	1 and 2	3
	Factor of safety	
Shear Tension, compression, bending Combined	1,89 1,25 1,11	2,5 1,67 1,43

NOTES
1. Factors of safety relate to tensile yield stress.
2. Combined stress = $\sqrt{\sigma_X^2 + \sigma_Y^2 - \sigma_X\sigma_Y + 3\tau^2}$
   Where σ_X and σ_Y are the combined axial and bending stresses in the X and Y directions respectively and τ is the combined shear stress due to torsion and/or bending in the X–Y plane.

Table 10.12.3 Winch/windlass tests

Test	Test load
Static brake – Primary	100% anchor line break strength (or 80% where stopper fitted, *see* 12.5.1)
Static brake – Secondary	50% anchor line break strength
Stopper (where fitted)	100% anchor line break strength
Motor stall test	Specified stall load

12.7.3 Each winch or windlass is to be tested on board the vessel in the presence of the Surveyor, to demonstrate that all main aspects including dynamic brakes function satisfactorily. The proposed test programme is to be submitted.

12.8 Type approval

12.8.1 Winches or windlasses may be Type Approved in accordance with LR's *Type Approval Scheme*. Where this Type Approval is obtained, the requirements of 12.7.1 may not be applicable.

■ *Section 13* Electrical and control equipment

13.1 General

13.1.1 The electrical installation is to be designed, constructed and installed in accordance with the relevant requirements of Pt 6, Ch 2.

13.1.2 Control, alarm and safety systems are to be designed, constructed and installed in accordance with the relevant requirements of Pt 6, Ch 1, together with the requirements of 13.2 to 13.4.

13.1.3 Reference should be made to the general requirements of Section 14 for thruster-assisted positional mooring systems.

13.2 Controls, indications and alarms

13.2.1 Adequate control, indication and alarm systems are to be provided to ensure satisfactory operation of the positional mooring system.

13.2.2 A suitable central control station is to be provided.

13.2.3 Where additional local control stations are provided, means of direct communication between the local and central control stations are to be arranged.

13.2.4 Indication of the following, as applicable, is to be provided at the central control station, and where local control is provided, at the local control station:

(a) Position of unit.
(b) Heading of unit.
(c) Anchor line tensions.
(d) Wind speed and direction.
(e) Offloading tanker status:
- position.
- heading.
- hawser tension.
- offloading hose connections status.

13.2.5 Alarms are to be provided for the following fault conditions, as applicable:

(a) Deviation from positional limits.
(b) Deviation from heading limits.
(c) Deviation from anchor line tension limits (high and low).
(d) Gyro compass fault.
(e) Position reference system fault.
(f) Wind speed and direction indicator fault.
(g) Offloading tanker deviation from attached limits.
(h) Control computer system fault.
(j) Turret/unit relative heading limit exceedence.

13.3 Control aspects – Disconnectable mooring systems

13.3.1 This sub-Section is applicable to units or ships which are disconnectable to avoid hazards or severe storm conditions.

13.3.2 Power, control and thruster systems and other systems necessary for the correct functioning of the positional system are to be provided and configured such that a fault in any active component will not result in a loss of position.

13.3.3 At least two automatic control systems are to be provided and arranged to operate independently.

13.3.4 Adequate controls are to be provided at the control station for satisfactory operation of the connect/disconnect mechanism.

13.3.5 Hydraulic and electrical systems are to be served by two means of power supply. Failure of the main supply is to activate an alarm.

13.3.6 Where the mooring system is designed on the basis of the unit or ship disconnecting at limiting environmental levels below the 100-year extreme case required by 4.3, means are to be provided to enable the rapid release of the unit or ship as applicable from the mooring system in an emergency. The quick-disconnect system is to be based on single operation at the control station, and may be independent of the normal control system.

13.3.7 Suitable fail-safe measures are to be provided to prevent inappropriate or inadvertent disconnection of the mooring system.

13.3.8 The reconnection of a disconnectable unit or ship is to be to the satisfaction of LR Surveyors.

13.4 Controls of winch and windlass systems

13.4.1 This sub-Section is applicable to mooring systems incorporating winches, windlasses, etc., which are used to actively control and adjust anchor line tensions in-service, or to release anchor lines in an emergency.

13.4.2 Adequate controls are to be provided at the local control station for satisfactory operation of the winch(es).

13.4.3 The braking system is to be arranged so that the brakes, when applied, are not released in the event of a failure of the normal power supply.

13.4.4 Standby power is to be provided to enable winch brakes to be released within 15 seconds in an emergency. The release arrangements are to be operable locally at each winch and from the central control position, and are to be such that the entire anchor line can be lowered in a controlled manner.

13.4.5 The standby power is to be such that during lowering of the anchor line it is possible to apply the brakes once and then release them again in a controlled manner.

13.4.6 Standby power is to be provided so that any anchor line stoppers or pawl mechanisms may be released from either the local or central control stations up to a line tension equal to the minimum rated break strength of the anchor line. These mechanisms are to be capable of release at the maximum angles of heel and trim under the damage stability and flooding conditions for which the unit is designed.

13.4.7 At least one position reference system and one gyrocompass or equivalent is to be provided, when applicable, to ensure the specified area of operation and heading deviation can be effectively monitored.

13.4.8 Position reference systems are to incorporate suitable position measurement techniques which may be by means of acoustic devices, radio, radar, taut wire, riser angle, gangway extension and angle or other acceptable means, depending on the service conditions for which the unit is intended.

13.4.9 A vertical reference sensor is to be provided, if applicable, to measure the pitch and roll of the unit.

13.4.10 Means are to be provided to ascertain the wind speed and direction acting on the unit.

13.4.11 The operation of winches, windlasses and associated brakes, chain stoppers and pawls is to be controlled locally from weather protected control stations which provide good visibility of the equipment and associated anchor handling operations.

13.4.12 A central control station, which may be located on the bridge or a separate manned control room, is to be provided from which brakes, chain stoppers and pawls can be remotely released.

13.4.13 For each anchor winch the respective local control station is to be provided with a means of indicating the following:

(a) Line tension.
(b) Length of line paid out.
(c) Line speed.

13.4.14 The indication required by 13.4.13(a), and (b), is to be repeated to the central control station and in addition a means of indicating the following is to be provided at this position:

(a) Mooring patterns and anchor line catenaries.
(b) Status of winch operation.
(c) Position and heading, *see also* 13.4.7.
(d) Gangway angle and extension, when applicable.
(e) Riser angle, when applicable.
(f) Wind speed and direction, *see also* 13.4.10.

13.4.15 Means of voice communication are to be provided between the central control station, each local control station and anchor handling vessels, when applicable.

13.4.16 Alarms are to be provided at the local and central control stations for the following fault conditions:

(a) Excessive line tension.
(b) Loss of line tension.
(c) Excessive gangway angle and extension, when applicable.
(d) Excessive riser angle, when applicable.

13.4.17 Alarms are to be provided adjacent to the winches and windlasses to warn personnel prior to and during any remote operation.

13.4.18 Alarms are to be provided at the central control station for the following fault conditions:
(a) When the unit deviates from its predetermined area of operation.
(b) When the unit deviates from its predetermined heading limits.
These alarms are to be adjustable but should not exceed specified limits. Arrangements are to be provided to fix and identify their set points.

■ *Section 14*
Thruster-assisted positional mooring

14.1 General

14.1.1 Where the positional mooring system is assisted by thrusters, as defined in Section 4, units complying with the requirements of this Section together with the requirements in Section 15 will be eligible for one of the following class notations as specified in 1.2:

TA(1) *See* 15.1
TA(2) *See* 15.2
TA(3) *See* 15.3.

14.1.2 Machinery items are to be constructed, installed and tested in accordance with the relevant requirements of Part 5, together with the requirements of 14.2 and Section 15.

14.2 Thrust units

14.2.1 Thruster installations are to be designed to minimise potential interference with other thrusters, sensors, hull or other surfaces which could be encountered in the service for which the unit is intended.

14.2.2 Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.

14.2.3 Steerable thrusters and thrusters having variable pitch propellers are to be provided with two independent supplies of motive power to the pitch and direction actuating mechanisms.

14.2.4 Each thruster unit is to be provided with a high power alarm. The setting of this alarm is to be adjustable and below the maximum thruster output.

14.2.5 The response and repeatability of thrusters to changes in propeller pitch or propeller speed/direction of rotation are to be suitable for maintaining the area of operation and the heading deviation specified.

14.2.6 The thrust unit housing is to be tested at a hydraulic pressure of not less than 1,5 times the service immersion head of water or 1,5 bar (1,5 kgf/cm^2), whichever is the greater.

14.3 Electrical equipment

14.3.1 The electrical installation is to be designed, constructed and installed in accordance with the relevant requirements of Pt 6, Ch 2, together with the requirements of 14.3.3 to 14.3.8, and the relevant requirements of Section 15.

14.3.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, defined in Pt 6, Ch 2,15 are to be complied with.

14.3.3 The total generating capacity is to be in accordance with 15.1.3, 15.2.8 and 15.3.8, as applicable.

14.3.4 Where the electrical power requirements are supplied by one generator set, on loss of power there is to be provision for automatic starting and connection to the switchboard of a standby set and automatic restarting of essential auxiliary services. For other requirements relevant to particular thruster-assisted class notations, *see* Section 15.

14.3.5 An alarm is to be initiated at the thruster-assisted positioning control station(s) when the total electrical load of all operating thruster units exceeds a preset percentage of the running generator(s) capacity. This alarm is to be adjustable between 50 and 100 per cent of the full load capacity, having regard to the number of electrical generators in service.

14.3.6 The number and ratings of power transformers are to be sufficient to ensure full load operation of the thruster-assisted positioning system even when one transformer is out of service. This does not require duplication of a transformer provided as part of a transformer/silicon controlled rectifier (SCR) drive unit.

14.3.7 Thruster auxiliaries, control computers, reference systems and environmental sensors are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practical and without the use of common feeders, transformers, converters, protective devices or control circuits.

14.3.8 Where the auxiliary services and positioning mooring thrusters are supplied from a common source, the following requirements are to be complied with:
(a) The voltage regulation and current-sharing requirements defined in Pt 6, Ch 2,8.4 are to be maintained over the full range of power factors that may occur in service.
(b) Where SCR converters are used to feed the thruster motors, and the instantaneous value of the line-to-line voltage wave-form on the a.c. auxiliary system busbars deviates by more than 10 per cent of $\sqrt{2}$ times the r.m.s. voltage from the instantaneous value of the fundamental harmonic, the essential auxiliary services are to be capable of withstanding the additional temperature rise due to the harmonic distortion. Control, alarm and safety equipment is to operate satisfactorily with the maximum supply system wave-form distortion, or be provided with suitably filtered/converted supplies.

(c) When the control system incorporates volatile memory it is to be supplied via uninterruptible power supplies provision for automatic starting and connection to the (UPS), *see also* Pt 6, Ch 1,2.9.

14.4 Control engineering systems – Additional requirements

14.4.1 The control engineering systems are to be designed in accordance with the relevant requirements of Section 13 together with the additional requirements of 14.4.2 to 14.4.3 and the relevant requirements of Section 15.

14.4.2 Indication of the following is to be provided at each station from which it is possible to control the thruster-assisted positioning system, as applicable:

- The heading and location of the vessel relative to the desired reference point or course.
- Vectorial thrust output, individual and total.
- Operational status of position reference systems and environmental sensors.
- Environmental conditions, e.g., wind speed and direction.
- Availability status of standby thruster units.

14.4.3 Alarms are to be provided for the following fault conditions where applicable:

- When the unit deviates from its predetermined area of operation.
- When the unit deviates from its predetermined heading limits.
- Position reference system fault (for each reference system).
- Gyrocompass fault.
- Vertical reference sensor fault.
- Wind sensor fault.
- Taut wire excursion limit.
- Automatic changeover to a standby position reference system or environmental sensor.
- Control computer system fault.
- Automatic changeover to a standby control computer system, *see* 15.3.3.

14.4.4 Suitable processing and comparative techniques are to be provided to validate the control system inputs from position and other sensors, to ensure the optimum performance of the thruster-assisted mooring system.

14.4.5 Abnormal signal errors revealed by the validity checks required by 14.4.4 are to operate alarms.

14.4.6 The control system for thruster-assisted positioning operation is to be stable throughout its operational range and is to meet the specified performance and accuracy criteria.

14.4.7 Automatic controls are to be provided to maintain the desired heading of the unit.

14.4.8 The deviation from the desired heading is to be adjustable, but is not to exceed the specified limits. Arrangements are to be provided to fix and identify the set point for the desired heading.

14.4.9 Sufficient instrumentation is to be fitted at the central control station to ensure effective control and indicate that the system is functioning correctly, *see* 14.4.2.

■ *Section 15* Thruster-assist class notation requirements

15.1 Notation TA(1)

15.1.1 For assignment of the notation **TA(1)**, in accordance with Section 4, the applicable requirements of Sections 13 and 14 together with 15.1.2 to 15.1.3 are to be complied with.

15.1.2 Centralised automated manual control of the thrusters is to be provided to supplement the position mooring system. The manual control system is to provide output signals to the thrusters via the manual controller to change the speed, pitch and azimuth angle, as applicable, as indicated at the central control station, *see* 13.2.

15.1.3 For electrically driven thruster systems, the total generating capacity of the electrical system is to be not less than the maximum dynamic positioning load together with the maximum auxiliary load. This may be achieved by parallel operation of two or more generating sets, provided the requirements of Pt 6, Ch 2,2.2 are complied with.

15.2 Notation TA(2)

15.2.1 For assignment of the notation **TA(2)**, in accordance with Section 4, the applicable requirements of Sections 13 and 14 together with 15.2.2 to 15.2.8 are to be complied with.

15.2.2 Automatic and manual control systems are to be provided to supplement the positional mooring systems and arranged to operate independently so that failure in one system will not render the other system inoperative, *see also* 15.1.2 for manual control.

15.2.3 The automatic control system is to utilise automatic inputs from the position reference system, the environmental sensors and line tensions, and automatically provide output signals to the thrusters to change the speed, pitch and azimuth angle, as applicable, such that the line tensions are optimised.

15.2.4 In the event of a failure of a reference or environmental sensor, the control systems are to continue to operate on signals from the remaining sensors without manual intervention.

15.2.5 In the event of line failure or failure of the most effective thruster, the unit is to be capable of maintaining its predetermined area of operation and desired heading in the environmental conditions for which the unit is designed and/or classed.

15.2.6 Control, alarm and safety systems are to incorporate a computer-based consequence analysis which may be continuous or at predetermined intervals and is to analyse the consequence of predetermined failures to verify that the anchor line tensions and position/heading deviations remain within acceptable limits. In the event of a possible hazardous condition arising as a result of the consequence analysis an alarm is to be initiated at the central control station.

15.2.7 The area of operation is to be adjustable, but is not to exceed the specified limits, which are to be based on a percentage of water depth, or if applicable a defined absolute surface movement. Arrangements are to be provided to fix and identify the set point for the area of operation.

15.2.8 For electrically driven thruster systems, the following requirements are to be complied with:

(a) Generating capacity, as defined in 15.1.3.
(b) With one generating set out of action, the capacity of maximum positioning load with the most effective thruster inoperative together with the essential services defined by Pt 6, Ch 2,1.5.
(c) Where generating sets are arranged to operate in parallel, the supplies to essential services are to be protected by the tripping of non-essential loads as required by Pt 6, Ch 2,6.9 and additionally, on loss of a running generator, a reduction in thrust demand may be accepted provided the arrangements are such that a sufficient level of dynamic position capability is retained to permit the three degrees of manoeuvrability of the unit.
(d) Indication of absorbed electrical power and available on-line generating capacity is to be provided at the main thruster-assisted positioning control station, *see* 14.4.1.
(e) Means are to be provided to prevent starting of thruster motors until sufficient generating capacity is available.

15.3 Notation TA(3)

15.3.1 For assignment of the notation **TA (3)**, in accordance with Section 4, the applicable requirements of Sections 13 and 14, together with 15.2.3 to 15.2.8 and 15.3.2 to 15.3.8, are to be complied with.

15.3.2 Two automatic control systems are to be provided and arranged to operate independently so that failure in one system will not render the other system inoperative.

15.3.3 In the event of failure of the working system the standby automatic control system is to be arranged to change over automatically without manual intervention and without any adverse effect on the vessel's station keeping capability. The automatic changeover is to initiate an alarm.

15.3.4 At least two position reference systems as defined by 13.4.8, and two gyrocompasses or equivalent, are to be provided.

15.3.5 At least two of each of the sensors as required by 13.4.9 and 13.4.10 are to be provided.

15.3.6 When two voyage recording systems are deployed, their outputs are to be compared and an alarm raised when a significant difference occurs.

15.3.7 The arrangement is to be verified by means of a Failure Mode and Effects Analysis (FMEA). Such components may include, but not be restricted to, the following:

- Mooring systems.
- Prime movers, e.g., auxiliary engines.
- Generators and the excitation equipment.
- Switchgear.
- Pumps.
- Thrusters.
- Fans.
- Valves, where power-actuated.

15.3.8 Control, alarm and safety systems are to incorporate a computer-based consequence analysis which may be continuous or at predetermined intervals and is to analyse the consequence of predetermined failures to verify that position and heading deviation remain within acceptable limits. In the event of a possible hazardous condition being indicated from the consequence analysis, an alarm is to be initiated.

■ *Section 16* Trials

16.1 General

16.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be based on the approved test schedules list as required by 1.4.1(d).

16.1.2 The suitability of the positional mooring and/or thruster-assisted positional mooring system is to be demonstrated during sea trials, observing the following:

(a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power.
(b) Response of the system under a set of predetermined manoeuvres for changing:
    - Location of area of operation;
    - Heading of the unit.
(c) Automatic thruster control and line tension optimisation.
(d) Monitoring and consequence analyses.
(e) Simulation of line breakage and damping.
(f) Continuous operation of the thruster-assisted positional mooring system over a period of 4 to 6 hours.

16.1.3 Two copies of the test schedules, as required by 1.4.1(d), signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the unit and the other submitted to LR.

■ *Section 1* Rule application

1.1 General

1.1.1 Masts, derrick posts, crane pedestals and similar supporting structures to equipment are classification items, and the scantlings and arrangements are to comply with the additional requirements of this Chapter.

1.1.2 Certain lifting appliances on special purpose units which are considered an essential feature of the unit are to be included in the classification of the unit. Elsewhere, classification of lifting appliances is optional and may be assigned at the request of the Owner on compliance with the appropriate requirements.

1.1.3 Where the lifting appliance is considered to be an essential feature of a classed unit, the special feature class notation **LA** will, in general, be mandatory.

1.1.4 Proposals to class lifting appliances on unclassed units will be specially considered.

1.2 Masts, derrick posts and crane pedestals

1.2.1 The scantlings of masts and derrick posts, intended to support derrick booms, and of crane pedestals are to comply with the requirements of LR's *Code for Lifting Appliances in a Marine Environmen*t (hereinafter referred to as LAME Code).

1.2.2 In addition to the information and plans requested in LR's LAME Code, the following details are to be submitted:
(a) Details of deckhouses or other supports for the masts, derrick posts or crane pedestals, together with details of the attachments to the hull structure.
(b) Details of any reinforcement or additional supporting material fitted to the hull structure in way of the mast, derrick post or crane pedestal.

1.2.3 Masts, derrick posts or crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into transverse or longitudinal bulkheads, or equivalent structure. Alternatively, the mast, derrick posts or crane pedestals may be carried into a deckhouse or equivalent structure, in which case the house is to be of substantial construction. Proposals for other support arrangements will be specially considered.

1.2.4 Deck plating and underdeck structure are to be reinforced under masts, derrick posts and crane pedestals. Where the deck is penetrated the deck plating is to be suitably increased locally.

1.2.5 The permissible stresses in the support structure are to be in accordance with Pt 4, Ch 5,2.

1.3 Lifting appliances

1.3.1 Offshore units fitted with lifting appliances built in accordance with LR's LAME Code in respect of structural and machinery requirements will be eligible to be assigned special features class notations as listed in Table 11.1.1. The notation will be retained so long as the appliances are found upon examination at the prescribed surveys to be maintained in accordance with LR's requirements.

Table 11.1.1 Special features class notations associated with lifting appliances

Cranes on offshore units	**PC**	Optional notation. Indicates that the unit's main deck cranes are included in class
Lifts	**PL**	Optional notation. Indicates that the unit's personnel lifts are included in class
Lifting appliances forming an essential feature of the unit e.g. Cranes on crane barges or units, lifting arrangements for diving on diving support units, etc.	**LA**	Mandatory notation. Indicates that the lifting appliance is included in class

1.4 Crane boom rests

1.4.1 With the crane boom in the stowed position, the structure of the crane boom support structure is to be designed for the maximum reaction forces in any operating condition, taking into account the maximum design environmental loadings and inertia forces due to motions of the unit.

1.4.2 The crane boom support structure is also to be verified in the emergency condition defined in Ch 8,1.4.

1.4.3 The permissible stresses in the crane boom support structure and the deck structure below are to be in accordance with Pt 4, Ch 5,2.

1.5 Runway beams

1.5.1 Runway beams are to be designed and tested *in situ* in accordance with a recognised Standard and marked with the safe working load, *see also* Appendix A.

1.6 Lifting padeyes

1.6.1 Padeyes attached to the main structure which are to be used with a rated lifting appliance are to be proof tested after installation and marked with the safe working load (SWL). The proof load is not to be less than 1,5 x SWL.

1.6.2 Lifting lugs are to be permanently marked with the SWL, tested after installation and NDE to the Surveyor's satisfaction. In agreement with LR, testing and NDE of lifting lugs with SWL < 1 tonne may be by sampling, provided design calculations can demonstrate a factor of safety greater than 2.

1.7 Access gangways

1.7.1 Pedestals and similar structures supporting installed gangways used for access to adjacent fixed installations are classification items and the scantlings and arrangements are to comply with the general requirements for crane pedestals and support structure in 1.2.

1.7.2 The gangway is to comply with the relevant statutory Regulations of the National Administration of the country in which the unit is registered and/or in which it is to operate and design calculations for the supporting structure are to be submitted.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to rigid and flexible risers, together with associated components, between the pipeline end manifold connection and the connection to the unit, *see* 1.4.2. The requirements of this Chapter are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.2 The requirements also apply to surface floating and suspended flexible loading hoses (as appropriate).

1.1.3 Submarine steel pipelines are to comply with the requirements contained in internationally recognised Codes and Standards.

1.1.4 The riser system will be considered for Classification on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

1.1.5 Risers may be arranged separately or in connected bundles comprising production risers together with other elements.

1.2 Class notations

1.2.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.2.2 Offshore units connected to product riser systems which comply with the requirements of this Chapter will be eligible for the assignment of the special features class notation **PRS**.

1.2.3 The service limits on which approval of the riser system has been based are to be included in the Operations Manual, *see* 2.5.

1.3 Definitions

1.3.1 The definitions in this Chapter are stated for Rule application only, and may not necessarily be valid in any other context.

1.3.2 **Riser system**. The riser together with its supports, component parts and ancillary systems such as corrosion protection, mid water arch, bend stiffeners, buoyancy modules, bend restrictors, bend stiffener latching mechanisms, etc.

1.3.3 **Riser**. A subsea flexible hose or rigid pipe leading down from the connection on the unit to a sea bed termination structure. Risers may have a variety of functions including liquid and gas export, water injection, chemical injection and controls, etc.

1.3.4 **Floating pipe**. A surface pipe between the single-point mooring or buoy and the ship manifold. The floating pipe is normally permanently attached to the single-point mooring.

1.3.5 **Riser support**. Any structural item used for connecting a part of the riser system to the unit.

1.3.6 **Riser components**. Valves, connections, etc., and similar apparatus incorporated in the riser system.

1.4 Scope

1.4.1 The following additional topics applicable to the special features class notation are covered by this Chapter:

- Welded steel risers.
- Flexible risers.
- Floating hoses.
- Pig traps.
- Valves, controls and fittings.
- Safety devices.
- Coverings and protection.
- Cathodic protection system.

1.4.2 Unless agreed otherwise with LR, the Rules consider the following as the main boundaries of the riser system:

- Any part of the riser system as defined in 1.3.2 from the sea bed termination to the first riser connector valves on the unit.
- The riser connector valves will normally be considered part of the offshore unit, unless agreed otherwise with LR.

1.5 Damage protection

1.5.1 Wherever possible, risers should be protected from collision damage either by suitable positioning within the unit or by protective structure provided for this purpose.

1.5.2 The risk of damage arising from impact loads should form an integral part of the riser assessment. The assessment should evaluate the risk and consequences to the installation of a release of hydrocarbon from the riser.

1.5.3 Design of the riser system should consider the avoidance of collisions between individual risers and anchor lines, etc., with the positioning system intact and in a single fault damaged state under the appropriate environmental conditions. Contact may be allowed in a single fault damaged state provided special external armoury is fitted to the risers in the interference regions, or where appropriate calculations and/or tests indicate that no damage to the risers will occur.

1.5.4 Risers designed to be capable of rapid release should not be damaged in the course of such release, nor should they inflict critical damage on other components.

1.6 Buoyancy elements

1.6.1 Where subsea buoyant vessels are provided as an inherent part of the riser system design, the requirements of Pt 3, Ch 2,2.3 of the *Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location* are to be complied with.

1.6.2 The loss of buoyancy of any one element is not to affect adversely the integrity of the riser system.

1.7 Emergency shut-down (ESD) system

1.7.1 An ESD system is to be provided to riser systems in accordance with Pt 7, Ch 1. This requirement is generally not applicable to conventional surface floating and suspended flexible loading hoses.

1.7.2 An ESD system philosophy should be developed for the installation based on appropriate hazard and safety assessments. Due consideration is to be given to the sequence of events in relation to overall installation safety.

1.7.3 To limit the quantity of flammable or toxic substances escaping in the event of damage to a riser, emergency shut-down valves are to be fitted. The valves and their control mechanisms should be positioned to offer the maximum protection to the unit in the event of damage.

1.7.4 Facilities are to be provided to make it possible at all times to isolate risers by means of valves.

1.7.5 Where appropriate, rapid disconnection of risers must be possible from at least one location. The assessment of how many locations to be provided, and where they should be situated, is to be based on the evaluation of various accident scenarios. Suitable fail-safe measures are to be provided to prevent inappropriate or inadvertent disconnection.

1.8 Recognised Codes and Standards

1.8.1 In general, the requirements in this Chapter are based on internationally recognised Codes and Standards for riser systems, as defined in Appendix A. Other Codes and National Standards may be used after special consideration and prior agreement with LR. When considered necessary, additional Rule requirements are also stated in this Chapter.

1.8.2 The agreed Codes and Standards may be used for design, construction and installation, but the additional requirements stated in the Rules are to be complied with. Where there is any conflict, the Rules will take precedence over the Codes or Standards.

1.8.3 The mixing of Codes or Standards for each equipment item or system is to be avoided. Deviation from the Code or Standard must be specially noted in the documentation and approved by LR.

1.8.4 Where National Administrations have specific requirements regarding riser systems, it is the responsibility of the Owner and Operators to comply with such Regulations.

1.9 Equipment categories

1.9.1 The approval and certification of riser systems are to be based on equipment categories agreed with LR.

1.9.2 Riser systems, including their associated components and valves, are to be divided into equipment Categories **1A**, **1B** and **II**, depending on their complexity of manufacture and their importance with regard to the safety of personnel and the installation and their possible effect on the environment.

1.9.3 The following equipment categories are used in the Rules:

1A Equipment of primary importance to safety, for which design verification and survey during fabrication are considered essential. Equipment in this category is of complicated design/manufacture and is not normally mass produced.

1B Equipment of primary importance to safety, for which design verification and witnessing the product quality are considered essential. Equipment in this category is normally mass produced and not included in Category **1A**.

II Equipment related to safety, which is normally manufactured to recognised Codes and Standards and has proven reliability in service, but excluding equipment in Category **1A** and **1B**.

1.9.4 A guide to equipment and categories is given in Appendix A. A full list of equipment categories for the riser system is to be agreed with LR before manufacture. Minor equipment components need not be categorised.

1.10 Equipment certification

1.10.1 Equipment is to be certified in accordance with the following requirements:

(a) **Category 1A**:
- Design verification and issue of certificate of design strength approval.
- Pre-inspection meeting at the suppliers with agreement and marking of quality plan and inspection schedule.
- Survey during fabrication and review of fabrication documentation.
- Final inspection with monitoring of function/ pressure/load tests and issue of a certificate of conformity.

(b) **Category 1B**:
- Design verification and issue of certificate of design strength approval, where applicable, and review of fabrication documentation.
- Final inspection with monitoring of function/ pressure/load tests and issue of certificate of conformity.

(c) **Category II**:
- Supplier's/manufacturer's works certificate giving equipment data, limitations with regard to the use of the equipment and the supplier's/manufacturer's declaration that the equipment is designed and fabricated in accordance with recognised Standards or Codes.

1.10.2 All equipment recognised as being of importance for the safety of personnel and the riser system is to be documented by a data book.

1.11 Fabrication records

1.11.1 Fabrication records are to be made available for Categories **1A** and **1B** equipment for inspection and acceptance by LR Surveyors. These records should include the following:
- Manufacturer's statement of compliance.
- Reference to design specification and plans.
- Traceability of materials.
- Welding procedure tests and welders' qualifications.
- Heat treatment records.
- Records/details of non-destructive examinations.
- Load, pressure and functional test reports.

1.12 Site installation of riser systems

1.12.1 The installation of riser systems is to be controlled by LR in accordance with the following principles:
- All Category **1A** and **1B** equipment, when delivered to site, is to be accompanied by a certificate of design strength approval and an equipment certificate of conformity and all other documentation.
- All Category **II** equipment, delivered to site, is to be accompanied by equipment data and a works' certificate.
- Control and follow-up of non-conformities/deviations specified in design certificates and certificate of conformity.
- Ongoing survey and final inspection of the installed riser system.
- Monitoring of functional tests after installation and connection to the unit in accordance with an approved test programme.
- Issue of site installation report.

1.13 Maintenance and repair

1.13.1 It is the Owner's/Operator's responsibility to ensure that an installed riser system is maintained in a safe and efficient working condition in accordance with the manufacturer's and design specification.

1.13.2 When it is necessary to repair or replace components of a riser system, any repaired or spare part is to be subject to the equivalent certification as the original, *see* 10.2.

1.14 Plans and data submissions

1.14.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules together with the additional plans and information listed in this Chapter.

■ *Section 2* Plans and data

2.1 General

2.1.1 Sufficient plans and data are to be submitted to enable the design to be assessed and approved. The plans are also to be suitable for use during construction, installation, hydrotesting, survey and maintenance of the riser system.

2.1.2 In general, engineering drawings and documents should be submitted electronically.

2.2 Specifications

2.2.1 Adequate design specifications, appropriate in detail to the approval required, are to be submitted for information.

2.2.2 Specifications for the design, construction and fabrication of the riser system, structure and associated equipment are to be submitted. The specifications are to include details of materials, grades/standards, consumables, construction and installation procedures and modes of operation with applicable design criteria. The specifications are also to include the proposed design codes.

2.2.3 Specifications and documentation are to be submitted, covering all instrumentation and monitoring systems proposed to cover the fabrication, installation and operating phases of risers, fittings and equipment.

2.3 Plans and data to be submitted

2.3.1 Plans and data covering the following items are to be submitted for approval, as relevant:

- Bend stiffeners.
- Bend stiffeners latching mechanisms.
- Bend restrictors.
- Buoyancy arches and fittings.
- Buoyancy modules.
- Construction and laying procedures.
- Corrosion protection system.
- Curvature bending stiffeners.
- Details of all attachments.
- Details of riser system control and communications.
- Details of sea bed.
- Emergency shut-down system and other safety devices, including pressure transient (surge) relief.
- End fittings.
- Instrumentation and communication line diagrams.
- Layout of risers and associated platform arrangements, including protection of risers.
- Leak detection system and hardware.
- Location survey showing name, latitude and longitude of terminal locations, location of isolating valves, position of platforms or other fabrications, shipping channels, presence of cables, pipelines and wellheads, etc.
- Mid water arches
- Quality Control and NDE procedures.
- Riser dimensions.
- Riser material specifications, including appropriate test results.
- Riser support details.
- Riser wall thickness tolerances.
- Sizes and details of expansion loops, reducers, etc.
- Test schedules for communication systems, controls, emergency shut-down systems and other safety devices, which are to include the methods of testing and test facilities provided.
- Tether arrangements
- Type and thickness of corrosion coating.
- Type and details of all pig traps, valves and control equipment, etc.
- Welding specification, details and procedures.

2.3.2 The following supporting plans and documents are to be submitted:

- Reference plans and listing of standard components, e.g., tees, reducers, connectors, valves, elbows, etc.
- Reference plans of anodes, sleeves, etc.

2.4 Calculations and data

2.4.1 The following is to be submitted where relevant to the riser system:

- Analyses of riser system behaviour including: strength, buckling, vortex shedding, on-bottom stability, displacements, vibration, fatigue, fracture and buckle propagation and minimum bend radii.
- Buoyancy and stability data for all risers.
- Burst pressure of flexible risers.
- Calculations and documentation of all design loads covering: manufacture, installation and operation.
- Corrosive nature of line contents.
- Corrosive nature of sea-water and sea bed soils.
- Current, tidal current and storm surge velocities and directions.
- Design cathodic protection potential.
- Damaging tension of flexible risers.
- Design life.
- Design pressure and temperature.
- Design throughput.
- Fluid to be conveyed. (The maximum partial pressure and dew point of H_2S, $C0_2$ and H_20 for gas risers).
- Ice conditions, which may affect riser system.
- Leak detection accuracy and response.
- Maximum and minimum operating temperatures including distributions along the riser.
- Maximum and minimum temperatures of water and air.
- Maximum operating pressure.
- Maximum Excursion Envelopes (MEEs) for riser system (in the x, y and z axes) to prevent damage. MEEs to be provided in the operational and survival conditions, with the mooring system in connected and disconnected (where appropriate) conditions.
- Marine growth density and thickness profiles (varying with water depth) plotted against time, over the field life.
- Product density.
- Sea bed geology and soil characteristics including stability and sand waves, etc.
- Sea bed topography and bathymetry in way of riser system and any possible deviation or future development.
- Seismic activity survey.
- Test pressure to be applied.
- Type, activity and magnitude of marine growth predicted.
- Wave heights, periods and directions.
- Wind velocities and directions.

2.5 Operations Manual

2.5.1 The allowable modes of operation including the maximum and minimum internal pressure, product temperature and flow rate together with the operating and maximum environmental criteria on which classification is based are to be stated in the unit's Operations Manual, as required by Ch 1,3.

2.5.2 The Manual is to contain instructions and guidance on any actions which need to be taken to satisfy environmental considerations and the safe operation of the riser system.

Section 3 Materials

3.1 General

3.1.1 The type and grade of materials chosen for the risers, valves and associated equipment are to be in accordance with the Rules for Materials or a recognised National or International Standard. In cases when a specification is not covered by LR's Rules, full details of the material specification, testing documentation and all properties are to be submitted for approval.

3.1.2 Materials are to be selected in accordance with the requirements of the design in respect of carriage of the product, strength, fatigue, fracture resistance and corrosion resistance.

3.1.3 Due consideration is to be given to temperature and other environmental conditions on the performance of the material, including toughness at the minimum operating temperature, the effects of corrosion, and other forms of deterioration both in service and whilst being stored or handled.

3.1.4 Riser material for H_2S-contaminated products (sour service) is to comply with the NACE MR0175/ISO15156 - *Petroleum and Natural Gas Industries – Materials for use in H_2S-containing Environments in Oil and Gas Production, see* Appendix A.

3.1.5 Steel grades for operation in areas where the design air temperature is below minus 20°C and in severe ice conditions (e.g., arctic waters), will be specially considered.

3.1.6 An approved system of corrosion control is to be fitted, where appropriate. Full details are to be submitted, *see* Pt 8, Ch 1.

Section 4 Environmental considerations

4.1 General

4.1.1 The Owner or designer is to specify the environmental criteria for which the riser system is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters.

4.1.2 The extreme environmental criteria to be taken into account in the riser system design are, in general, to be based on a return period of:
(a) 50 years for Mobile Offshore Units.
(b) 100 years for Floating Offshore Installations at a Fixed Location.
See also Pt 4, Ch 3,4.

4.2 Environmental factors

4.2.1 The following environmental factors are to be considered in the design of the riser system:
- Air and sea temperatures.
- Current.
- Fouling.
- Ice.
- Water depth.
- Wave.
- Wind.

4.2.2 Environmental factors to be accounted for in the design loadings are contained in Pt 4, Ch 3,4 together with the additional considerations below.

4.3 Waves

4.3.1 When using acceptable wave theories to determine local wave velocities for smooth cylindrical members, appropriate hydrodynamic coefficients should be used. These values should be modified to account for marine growth, for proximity to the sea bed, or structural members on the unit.

4.4 Current

4.4.1 Where a current acts simultaneously with waves, the effect of the current is to be included. The current velocity is to be added vectorially to the wave particle velocity. The resultant velocity is to be used to compute the total force.

4.4.2 In the absence of more detailed information, the distribution of current velocity with depth may be assumed to vary according to the 1/7th power law.

4.5 Vortex shedding

4.5.1 Consideration is to be given to the possibility of vibration of structural members due to von Karman vortex shedding. (This is to apply to wind on exposed risers, and to wave and current on immersed risers).

4.6 Ice

4.6.1 Riser systems intended for operation in ice are to be designed to minimise the effect of ice loading. Proposals are to be submitted for consideration.

Section 5
Design loadings

5.1 General

5.1.1 All modes of operation are to be investigated using realistic loading conditions, including buoyancy, unit motions and gravity loadings and operational loads (temperature, pressure, etc.) together with relevant environmental loadings due to the effects of wind, waves, currents, vibrations, ice, and where necessary, the effects of earthquake, sea bed supporting capabilities and friction, temperature, fouling, etc.

5.1.2 The design of the riser system is to take account of all loads which can be imposed during its service life.

5.1.3 The design is also to take account of loads related to the construction, transportation and site installation stages.

5.2 Dead loads

5.2.1 All gravity loadings are to be taken into account and should include self-weight of the riser system and attachments. The deadweight of contents is to be included.

5.2.2 Buoyancy of risers including attached equipment is to be taken into account.

5.2.3 Constraints and loads arising from supports and attachments should be taken into account. Also any scour or subsidence of sea bed should be assessed.

5.3 Live loads

5.3.1 Static pressure, pressure surge transients and any peak 'hammer-blow' effects are all to be considered, together with corresponding temperatures.

5.3.2 Dynamic inertial vibrations and flutter induced by any activation, including vortex shedding, are to be considered.

5.4 Environmental loads and motions

5.4.1 The environmental loading on a riser system and its motion responses are to be determined for at least the design environmental conditions given in Section 6. Dynamic effects are to be considered.

5.4.2 The loads and motions can be established by model testing or by suitable calculations or both. The possibility of resonant motion is to be fully investigated.

5.4.3 Account is to be taken of the effect of marine growth. Both increase in the dimensions and the change in surface characteristics are to be considered.

5.4.4 Where model testing is to be adopted:

(a) the test programme and the model test facilities are to be to LR's satisfaction;

(b) the relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined;

(c) the tests are to be of sufficient duration to establish low frequency motion behaviour; and

(d) the model testing is required to give suitable data pertaining to both strength and fatigue design aspects of the riser system.

5.5 Other loadings

5.5.1 Loads imposed during site installation, including those due to motion of the laying ship/unit, are to be assessed and taken into account. The curvature taken up during laying and loads imposed thereby are to be assessed and arrangements made for laying procedures to avoid any damage or overstress.

5.5.2 Hydrostatic effects are to be included in the design. Hydrostatic loading can be taken as the difference between internal and external pressures, as appropriate.

5.5.3 The riser system design should also take account of accidental loading, where relevant, and required test loads, *see* Section 9.

5.5.4 The riser system is to be designed to withstand the most unfavourable combinations of pressure, temperature and environmental loadings under normal operating conditions combined with the effects of the most severe single fault that might arise in the positioning system.

5.5.5 Scouring effects are to be considered for the support conditions of steel flexible risers at the touchdown locations.

Section 6
Strength

6.1 General

6.1.1 This Section defines the strength requirements, including static and dynamic aspects, for welded steel riser systems, flexible riser systems and hoses.

6.1.2 The design is to be analysed in accordance with acceptable methods and procedures and the resultant stresses or factors of safety determined.

6.1.3 In general, the strength of the riser system is to be determined from a three-dimensional analysis. Only if it can be demonstrated that other methods are adequate will they be considered.

6.1.4 The riser system is to be designed such that under transient operating conditions the maximum allowable operating pressure may not be exceeded by more than 10 per cent.

6.2 Structural analysis

6.2.1 The loading combinations considered are to represent all modes of operation so that the critical design cases are established.

6.2.2 All loads applicable to the design, as defined in Section 5, are to be fully covered in the loading combinations.

6.2.3 A fully representative number of design cases are to be defined, each of which should be associated with appropriate environmental conditions and allowable yield ratios or factors of safety. The design cases are to cover all critical aspects of riser system installation, testing and operation.

6.2.4 A detailed analysis of the riser system, including interaction with pipeline and expansion loop is to be carried out. This is to take account of thermal, hydrodynamic, gravity, buoyancy and pressure effects and vessel motions. Modelling is to describe riser geometry and stiffness, and soil interaction, including loss of contact.

6.2.5 Riser supports and stiffener bend restrictor forces are to be determined, and strength checks carried out.

6.3 Flexible risers and hoses

6.3.1 The design of flexible risers and associated appurtenances and fittings is to be based on sound engineering principles and practice, and is to be in accordance with recognised National or International Standards or Codes of Practice. Design calculations are to be submitted and, where considered necessary, LR will carry out independent analysis of the strength and stability of the flexible risers, *see* Appendix A, A1.2.10.

6.3.2 For all critical loading combinations relevant to the design axial loading, internal/external pressure and radius of curvature are to be considered in a rational manner.

6.3.3 Other factors which adversely affect the integrity of the riser such as abrasion, ageing, corrosion, fatigue and fire are also to be considered.

6.3.4 For fatigue *see* 6.4.6; however, endurance curves should also account for fluid permeation through polymers and potential accidental ingress of sea-water resulting from damage to the external sheath.

6.3.5 Special attention is to be given to riser end fittings to ensure effective bonding, pressure containment and load transfer.

6.3.6 In general, riser displacements are to achieve acceptable clearances with adjacent risers, mooring lines, unit structures and the sea bed. However, in extreme cases interference may be allowed, *see* 1.5.3.

6.3.7 Critical design parameters are to be demonstrated by means of appropriate tests and calculations.

6.4 Welded steel risers

6.4.1 The design of steel risers and associated appurtenances and fittings is to be based on sound engineering principles and practice, and is to be in accordance with recognised National or International Standards or Codes of Practice. Design calculations are to be submitted and, where considered necessary, LR will carry out independent analysis of the strength and stability of the steel risers, *see* Appendix A, A1.2.10.

6.4.2 **Yielding**: For any particular location, two stress intensity calculations will be required, as follows:

(a) Hoop stress calculations are to be made utilising the minimum specification wall thickness less corrosion allowance, as appropriate.
(b) All axial stresses arising from end load, bending moment, shear and torsion are to be combined with hoop stress to give an equivalent stress based on the Mises-Hencky criterion to conform with specified yield ratio limits. For this purpose, nominal section dimensions may be used.

6.4.3 **Vortex shedding response**:

(a) The effects of vortex-induced oscillations are to be accounted for. The effect of axial forces on natural frequency is to be included.
(b) The restraining effect of external spans, and relief due to wave and current directionality may be included provided that sufficient environmental data is available.
(c) In all cases, the effect of vortex shedding on fatigue life is to be checked.

6.4.4 **Buckling**. Local and overall buckling of the riser is to be checked for all locations and loading conditions for which free spans may arise. The worst combinations of axial and lateral loading are to be considered.

6.4.5 **Stress concentrations**. The effect of notches, stress raisers and local stress concentrations is to be taken into account in the design of the load-carrying elements.

6.4.6 **Fatigue**:

(a) Fatigue damage due to cyclic loading is to be considered in the design of the riser. The cyclic loading due to internal (contents) pressure fluctuations and external environmental loadings is to be taken into account. The extent of the fatigue analysis will be dependent on the mode and area of operations.

(b) Fatigue design calculations are to be carried out in accordance with the analysis procedures and general principles given in Pt 4, Ch 5,5, or other acceptable method, and the fatigue life calculations are to be based on the relevant stress range/endurance curves applicable to the service environment incorporating appropriate stress concentration factors .

(c) The minimum factors of safety on fatigue life are not to be less than as required by Pt 4, Ch 5.5.6.

6.4.7 **Plastic analysis**. Where plastic design methods are to be employed, the load factors will be specially considered.

6.5 Pig trap

6.5.1 Pig traps are to be designed to the requirements of a recognised pressure vessel code and since they are considered as part of the riser and associated equipment the hoop stress is not to exceed 60 per cent of the minimum yield stress of the material.

6.6 Riser supports and attachments

6.6.1 The riser supports and other attachments are to be designed to meet suitable structural design codes. Where the supports are attached to the structure of the unit the permissible stresses in the structure are to comply with Pt 4, Ch 5,2.

6.7 Mechanical items

6.7.1 The design of components such as valves and similar apparatus is to be in accordance with an acceptable design method or recognised Code or Standard.

■ *Section 7* Welding and fabrication

7.1 General

7.1.1 Welding, weld procedures and approval of welders are to be in accordance with the general requirements of Pt 4, Ch 8. When agreed with LR, the fabrication of riser systems may be in accordance with a recognised Code or Standard, *see* Appendix A.

7.1.2 The proposals for NDE procedures are to be agreed with LR prior to the commencement of construction.

7.1.3 All butt welds are to be subjected to 100 per cent NDE. Examination by radiography is to be to a Standard acceptable to LR, e.g., ISO 17636: *Non-destructive testing of welds – Radiographic testing of fusion welded joints*, with acceptance criteria as detailed in the Construction Code, or BS 4515: *Specification for welding of steel pipelines on land and offshore*, if not specified in the Code. Proposals for examination by ultrasonics are to be submitted for review and acceptance.

7.1.4 All defective sections of welds are to be cut out, carefully re-welded and re-examined.

7.1.5 Weld procedures for repairs and alterations are to be qualified and approved by LR.

■ *Section 8* Installation

8.1 General

8.1.1 Specifications covering the site installation procedures are to be submitted for approval.

8.2 Location Survey

8.2.1 Specifications, plans and data are to comply with 2.3.1. Additional data is to be submitted specifying sea bed preparation, extent and means of execution and survey prior to installation.

8.2.2 The construction specification is to specify the tolerance within which the riser system is to be positioned.

8.3 Installation procedures

8.3.1 The equipment used for operations is to be agreed by LR for the processes specified.

8.3.2 Individual risers, equipment, fittings and sub-assemblies are to be handled and stored with care, especially components with anodes or heavy anode bracelets. No components are to be stored in a manner which will cause damage or deformation.

8.3.3 All components and sub-assemblies are to be inspected before installation and be approved to the satisfaction of the Surveyor.

8.3.4 The installation of the riser is not to introduce any unscheduled loading and the transfer of loading to riser supports is to be shown to be in accordance with design specifications.

8.3.5 All monitoring systems are to be operated and calibrated to the Surveyor's satisfaction during all laying and installation operations.

8.4 Completion Survey

8.4.1 As soon as is practicable following installation and prior to start-up, a survey of the entire riser system is to be carried out.

■ *Section 9* Testing

9.1 Hydrostatic testing

9.1.1 The requirements of 1.10, 1.11 and 1.12 regarding certification and testing are to be complied with.

9.1.2 **Steel risers**:

(a) The riser system is to be hydrostatically tested after installation. Hydrostatic Testing Procedures are to comply with recognised international Codes and Standards.

(b) A written procedure is to be developed before hydrostatic testing commences. The acceptance criteria are to be agreed by LR.

9.1.3 **Flexible risers**. For flexible risers, pressure testing includes acceptance tests in the factory and hydrostatic test after installation. The acceptance test pressure should be in accordance with international Codes and Standards for flexible risers.

9.1.4 It is permissible to have pressure variations during a hydrostatic test provided they can be explained in terms of temperature changes and/or motions of the riser system.

9.1.5 In order to calculate the effect of temperature on pressure, it is essential that the temperature of the fluid in the pipe is measured and recorded at the same time as each pressure measurement is made and recorded. Ambient air or sea-water temperature are not relevant.

9.1.6 As a minimum, the temperature is to be measured near each end of the riser. Preferably at least one transducer on the sea bed part of the riser should also be provided.

9.1.7 Temperature sensors attached to the outside of the steel wall of a riser and insulated from the thermal effects of the sea are acceptable provided the test medium has been in the riser for at least 24 hours before the test is started, in order to allow the temperature of the fluid and steel to stabilise.

9.1.8 When conducting a hydrostatic test of a riser, the following requirements are to be complied with:

(a) The pressure (and temperature, if applicable) is to be continuously recorded for the duration of the test on a chart recorder.

(b) The chart is to be signed by the Surveyor at the beginning and end of the test.

(c) Pressure (and temperature, if applicable) readings are to be made at intervals not greater than 30 minutes and tabulated.

(d) Where temperature readings are to be taken the line is to be filled at least 24 hours before the test to enable the temperature to stabilise.

(e) The results of a hydrostatic test are to be recorded by a dossier containing the following:
- Copies of all charts made during the test.
- Copies of all tables of pressure readings (and temperature readings where applicable) made during the test.
- Copies of calibration certificates for the pressure recorders used.
- Calculations demonstrating temperature correction to pressure change where applicable.

9.1.9 The sections of riser are to be hydrostatically tested at the place of manufacture in accordance with Chapter 6 of the Rules for Materials or the relevant National Standard.

9.1.10 Before a consent to start-up a riser can be given, evidence of a satisfactory hydrostatic test is to be provided. The evidence is to relate to a test completed during the 12 months prior to the date of application for the consent to start up.

9.2 Buckle detection

9.2.1 An adequate examination is to be carried out to determine that the completed riser is free from buckles, dents or similar damage.

9.3 Testing of communications, controls and safety systems

9.3.1 Communication systems, remote and automatic controls, emergency shut-down systems and other safety devices are to be tested in accordance with the approved test schedules required by 2.3.1.

■ *Section 10* Operation and repairs

10.1 Operation procedures

10.1.1 A written operation procedure is to be prepared and issued prior to the riser system being put into operation. One operation procedure may, where applicable, cover several riser systems of the same type.

10.1.2 Where a riser system forms part of a system covering other lines, platforms, terminals, etc., the operating procedure is to embrace those parts of the entire system which are relevant to the operation of the riser system.

10.1.3 In order to minimise the risk of damage to the riser system, it is the Owner's/Operator's responsibility to ensure that supply boat approach routes to the installation are strictly controlled. A mooring procedure is to be produced which clearly indicates safe and hazardous anchoring areas.

10.1.4 Operation procedures are to be written in English with translations into other languages, as necessary, for the operating personnel involved.

10.2 Repairs

10.2.1 It is the Owner's responsibility to inform LR of any defects found. The exact location, nature and extent of the defects are to be stated. The requirements of 1.13 are to be complied with.

10.2.2 Plans and particulars of any proposed repairs are to be submitted for approval. All repair work is to be carried out to the satisfaction of LR's Surveyors.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are supplementary to those given in the relevant Parts of the Rules, and apply to buoys, deep draught caissons, turrets and other special structures. Requirements are given in this Chapter for the following special structures which are used in association with floating units:
(a) Subsea buoyant vessels.
(b) Mooring towers.

1.1.2 The Rules also cover mooring yokes, loading arm arrangements, hinged joints and support structures on floating units.

1.1.3 These Rules assume that floating moored units will be tethered with catenary-type mooring cables attached to the sea bed by anchors, gravity blocks or piles. Proposals for the use of pivot arms or other methods of tethering will be specially considered, *see* Sections 4 and 6.

1.1.4 Requirements for positional mooring systems are given in Chapter 10.

1.1.5 Foundations for mooring systems are to comply with Chapter 14, *see also* 4.1.10.

1.1.6 Buoys and other floating units may be fitted with pipelines or risers for loading and unloading linked ship/unit and additionally be fitted with crude oil bulk storage tanks, process plant facility, power generating capability, accommodation modules and similar facilities.

1.1.7 Units with crude oil or liquefied gas bulk storage tanks and/or production and process plant are to comply with the applicable requirements of Chapters 3 and 8.

1.2 Definitions

1.2.1 The definitions in this Chapter are stated for Rule application only and may not necessarily be valid in any other context.

1.2.2 **Buoy**. A floating mooring facility secured by a flexible tether or tethers to the sea bed, but excluding the other unit types defined in Pt 1, Ch 2,2.1.

1.2.3 **Deep draught caisson units** are single column floating units which operate at a deep draught in relation to their overall depth.

1.2.4 **Subsea buoyant vessel**. A submerged structure with positive buoyancy secured by a flexible tether or tethers to the sea bed and used to support flexible risers.

1.2.5 **Mooring tower**. A structure for single point mooring which is attached directly to the sea bed. The tower may be a single or multiple member structure and can be fixed to the sea bed, or articulated by means of a universal joint attached to the sea bed.

1.2.6 **Single-point mooring**. An offshore mooring facility based on a single buoy or single tower. A single-point mooring will allow a moored ship/unit to weathervane, and is normally associated with the transfer of oil, gas, and other fluids to or from the ship/unit. The following are among the most common types of single point moorings:
- CALM – catenary anchor leg mooring.
- SALM – single anchor leg mooring.
- Mooring tower.
- Turret mooring.

1.2.7 **Multi-point mooring**. A mooring facility embodying a number of separate buoys or mooring points. A multi-point mooring terminal is used to hold a ship/unit on a general constant heading and can incorporate facilities for the transfer of oil, gas and other fluids.

1.2.8 **Turret mooring**. A single-point mooring variant where the slewing function, allowing complete or partial weathervaning, forms an integral part of the unit. Turret mooring is mainly applicable to permanently moored surfac-type units.

1.2.9 **Spread mooring**. A multi-line mooring system designed to maintain an offshore unit on an approximately fixed heading.

1.2.10 **Mooring hawser**. A mooring rope connecting a ship/unit to a single-point mooring or buoy. Only a hawser permanently attached to a single-point mooring or buoy will be included in the classification of the installation.

1.2.11 **Mooring yoke**. A structural arm connecting a ship/unit to a single-point mooring or buoy. A yoke is normally used for permanently moored units.

1.3 Pipelines and power cables

1.3.1 Where pipelines, power cables, etc., are incorporated into or trail from single-point mooring installations, details of their number, position, size and method of attachment are to be submitted in order that their effect on wave forces, etc., acting on the structure, and of any restraining forces that they may impose, can be assessed.

1.3.2 For units with production and process plant, the boundaries for classification are to be as defined in Ch 8,1.3.

1.3.3 Pipelines carrying high pressure fluids, cables carrying high energy electricity supplies and cable carrying control signals critical to the safety of the unit, or to its operational reliability, are to be located in suitable positions on the unit in order to avoid accidental damage by moored ships/units, maintenance craft, or other sources which may cause large impact loads. Where this is impracticable, they are to be adequately protected and the arrangements submitted for approval.

1.3.4 If a floating unit is to be tethered in way of an existing wellhead, pipelines or high energy power cables, sufficient plans and details are to be submitted to enable Lloyd's Register (LR) to fully assess the following:
(a) The nature and size of the wellhead, pipeline or cable.
(b) The methods and arrangements to be employed to avoid accidental damage during the on-site installation.
(c) Method and means for emergency release.

NOTE
This information is required whether the pipework and cables are permanent or temporary and whether they are situated above water or subsea.

1.3.5 Where a caisson, buoy or mooring tower is fitted with risers/pipelines intended for the loading or discharge of oil or gas, the Rules consider the following as the main boundaries of the installation for classification, unless agreed otherwise with LR:
(a) Any part of the pipeline system located on the structure including the riser connector valves, but excluding the risers is considered part of the installation.
(b) The shut-down valve at the export outlet from the pipeline system to the storage or offloading facility.
(c) Where a floating or trailing riser is stowed on a reel, the Rules apply to the reel, but not the flexible riser, *see also* Chapter 12.

1.3.6 Where power cables are attached to the structure for the purpose of supplying electricity to a moored ship/unit, etc., the extent, if any, of cable included in the class of the structure will be specially considered by LR.

1.4 Class notations

1.4.1 The Regulations for classification, and the assignment of class notations, are given in Pt 1, Ch 2, to which reference should be made.

1.4.2 Buoys and single-point moorings complying with the requirements of this Chapter and the relevant Parts of the Rules, will be eligible for the assignment of one of the following type class notations, as applicable:
- Mooring buoy.
- Single-point mooring buoy.
- Tanker loading terminal.
- Mooring tower.
- Articulated mooring tower.

1.4.3 Deep draught caisson units will be eligible for the assignment of a type class notation in accordance with the unit's function, *see* Chapter 3. In addition a descriptive note will be added in the ClassDirect Live website, e.g., '**Deep draught caisson unit**'.

1.4.4 Associated integral mooring equipment, including anchors, mooring lines and their connections to the sea bed, will generally be included in the class of an installation, *see* Pt 1, Ch 2, 2.1.2. For mooring hawsers, *see* Section 5.

1.4.5 In the case of ship units the following components will generally be considered from the Classification aspects as part of the installation:
- Internal and external turrets.
- Mooring arms and yokes.
- Associated mooring equipment and mooring lines attached to the unit, and their anchors or connections to the sea bed.

1.4.6 Units with oil or liquefied gas bulk storage tanks or production/ process plant may be assigned type class notations in accordance with Chapter 3.

1.4.7 Product riser systems which comply with the requirements of Chapter 12 will be eligible for the special features notation **PRS**.

1.4.8 When a unit is to be verified in accordance with the Regulations of a Coastal State Authority, an additional class notation may be assigned in accordance with Pt 1, Ch 2.

1.4.9 Vessels designed for offshore loading should have the arrangements for offshore loading designed and constructed in accordance with suitable standards. For vessels classed LR, the requirements are outlined in Pt 7, Ch 6 of the Rules for Ships.

1.5 Scope

1.5.1 The following additional topics applicable to the type class notation of buoys and special installations are covered by this Chapter:
- General arrangement.
- Structural arrangements.
- Supporting structures to mooring systems and marine risers.
- Structural arrangement of oil storage tanks.
- Piping and piping systems.
- Watertight subdivision.
- Subsea buoyant vessels.
- Mooring towers.
- Turret structures.

- Gravity base.
- Mechanical parts, including bearings, universal joints and swivels.
- Mooring arms, yokes or hawser.
- Piping and cargo transfer systems located on the unit.
- Hazardous areas and ventilation.
- Pollution prevention.

1.6 Installation layout and safety

1.6.1 In principle units engaged in production and/or crude oil storage are to be divided into main functional areas in accordance with the requirements of Chapter 3.

1.6.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration. Additional requirements for the fire safety on units with production and process plant are given in Pt 7, Ch 3, *see also* Pt 1, Ch 2,1.

1.6.3 Additional requirements for safety systems and hazardous areas are given in Part 7.

1.6.4 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas and be protected and separated from production and wellhead areas.

1.6.5 Suitable arrangements are to be incorporated in the design to enable supply and maintenance craft to come along side as necessary and to moor safely while maintenance staff and equipment are being transferred to, or from, the installation.

1.6.6 Protection against damage which might otherwise be caused by impacts from moored ships/units over-riding the mooring installations or by supply and maintenance craft coming along side is to be provided. This protection is to include suitable fendering, adequately reinforced landing platforms or their equivalent, *see also* Pt 4, Ch 3,4.16.

1.6.7 Proper means of access are to be provided for maintenance and survey. Arrangements are to include a suitable platform or other landing area. It is the Owner's responsibility to provide suitable ladders, where the height of the deck is too great to facilitate direct access of personnel from maintenance craft.

1.7 Watertight and weathertight integrity

1.7.1 The general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

1.7.2 Floating units and subsea buoyant vessels are to have adequate buoyancy and stability in both intact and damage conditions, *see* Pt 4, Ch 7. They are to be sub-divided by watertight divisions, especially in zones where there is a risk of collision.

1.7.3 When requested, LR will give special consideration to the incorporation of equivalent approved means of protection against accidental sinking on buoys and subsea buoyant vessels. Where compartments are to be filled with foam, full details are to be submitted for approval.

1.7.4 The integrity of the weather deck of buoys and other floating structures is to be maintained. Where items of plant equipment penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in deckhouses fully complying with the Rules. Full details are to be submitted for approval.

1.8 Plans and data submission

1.8.1 Plans are to be submitted for approval as required by the relevant Parts of the Rules together with applicable plans, calculations and information to cover the additional topics listed in this Chapter, as applicable.

1.8.2 A single copy of the following supporting plans, data, calculations or documents are to be submitted:

- Anchors and tether system components.
- Motion envelopes (single-point mooring, risers and tethers, as applicable).
- Floating stability.
- Strength and fatigue of structural and mechanical parts.
- Design specification.
- Environmental report.
- General arrangement.
- Materials specification.
- Model test report.
- Operating instructions.
- Loadout and site installation procedure.

■ *Section 2* Floating structures and subsea buoyant vessels

2.1 Floating structures

2.1.1 The structural design and the general hull strength of buoys and deep draught caissons are to comply with the requirements of Part 4 taking into account the equipment weights and forces imposed on the structure.

2.1.2 The supporting structure below swivels and other equipment is to be designed for all operating conditions and environmental loads as defined in Part 4.

2.1.3 The structure and arrangement of units with crude oil bulk storage tanks and/or production and process plant are also to comply with the requirements of Chapters 3 and 8, as applicable.

2.1.4 Critical joints, depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing), are to be avoided wherever possible. Where unavoidable, plate material with suitable through thickness properties will be required, *see* Ch 3,8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Moored floating structures supporting multi-point mooring line arrangements are to be assessed for the maximum combined forces to which they may be subjected to in service.

2.1.6 Account is to be taken of wave slamming effects, where appropriate.

2.1.7 Floating structures, including highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures are to be assessed for local strength as required in Part 10 and for fatigue damage due to cyclic loading in accordance with Pt 4, Ch 5,5.

2.1.8 For mechanical items for bearings and swivels, *see* Section 6.

2.2 Permissible stresses

2.2.1 The permissible stresses in floating structures are to comply with Pt 4, Ch 5, but the minimum scantlings of the local structure are to comply with Pt 4, Ch 6.

2.3 Subsea buoyant vessels

2.3.1 Where a classed installation is to be assigned the notation **PRS** in accordance with Chapter 12, riser systems incorporating subsea buoyant vessels are to comply with the requirements of this sub-Section.

2.3.2 Where subsea buoyant vessels are used in association with other systems, they will be specially considered from the classification aspects.

2.3.3 Subsea buoyant vessels are to be designed for all external operating loads and the maximum pressure head to which the structure may be subjected to in service or during installation, *see* Pt 4, Ch 3,4.14.

2.3.4 The scantlings of the shell boundaries and framing are to be determined from an internationally recognised Pressure Vessel Code.

2.3.5 All vessels are to have positive buoyancy, when subjected to their design external loads, when any one internal compartment is flooded. Special consideration will be given to vessels with compartments filled with foam, *see* 1.7.

2.3.6 The local structure is to be suitably reinforced in way of the loads imposed by riser systems, and other external loads and the requirements of 2.1.4 are to be complied with as applicable.

2.3.7 Internal watertight bulkheads are to withstand the flooding of any single compartment. The scantlings of watertight bulkheads are to comply with Pt 4, Ch 6, with h_4 determined in accordance with 2.3.3.

■ *Section 3* Turret structures

3.1 General

3.1.1 Turret structures supporting multi-point mooring line arrangements are to be assessed for the maximum combined forces to which they may be subjected to in service. The turret structure is to be suitable for the appropriate maximum single-point mooring line loads and in addition the critical mooring line group loadings.

3.1.2 Environmental criteria and loading are in general to be in accordance with Part 10.

3.1.3 Account is to be taken of wave slamming effects, where appropriate.

3.1.4 When an internal turret is designed as a stiffened shell, the scantlings of plating and stiffeners are not to be less than required by Table 7.7.1 in Pt 4, Ch 6 as a deep tank bulkhead, using a load head h_4 measured vertically from the point of consideration to the top of the turret well.

3.1.5 Permissible stresses for direct calculations are to be in accordance with Pt 4, Ch 5,2.

3.1.6 The sealing arrangements, where fitted, between internal turrets and circumturret well bulkheads will be specially considered.

3.1.7 The turret structure, including structural supports in way of bearings and highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures, are to be assessed for local strength as required in Part 10 and for fatigue damage due to cyclic loading in accordance with Pt 4, Ch 5,5.

3.1.8 Suitable access arrangements are to be provided to allow inspection and maintenance of turret structural and mooring system components during service. A planned procedure for the inspection of the structure and mooring system components is to be provided, as required by Pt 1, Ch 2.

3.1.9 Special consideration is to be given in design to load transfer together with the effect of hull deformations at the interface of the turret support structure with the main hull structure.

3.1.10 The scantlings of the circumturret well bulkheads, turret support arrangements and hull backup structure are to be in accordance with Part 10.

3.1.11 For mechanical items such as bearings and swivels *see* Section 6.

3.1.12 The structure of hawsepipes and their supports is to be designed to withstand the imposed static and dynamic loads. Plating and framing in way of hawsepipes are to be reinforced as necessary. All relevant loads as defined in Chapter 3 are to be considered and the permissible stresses due to overall and local effects are to be in accordance with Pt 4, Ch 5,2.

3.1.13 Hawsepipe components are to be of ample thickness and of a suitable size and arrangement to house the mooring cables efficiently. Due consideration is to be given, as far as practicable, to minimise the effects bending and chafing on the mooring cables.

■ *Section 4* **Mooring arms and towers**

4.1 General

4.1.1 Mooring arms and towers are to be designed for the maximum mooring loads and direct wave loading to which they may be subjected in service, and design calculations are to be submitted. The loadings on lattice type structures are to be specially considered and agreed with LR.

4.1.2 The structure is to be designed for the most unfavourable of the following combined loading conditions:
(a) maximum gravity and functional loads.
(b) design environmental loads and associated gravity and functional loads.
(c) design environmental loads and associated gravity and functional loads after credible failures.

4.1.3 The structure is to be investigated for loading condition 4.1.2(c) to assess the effect of the failure of a single slender tubular (or similar) member. The permissible stress levels after credible failures are given in Pt 4, Ch 5,2.1.1(c). When stress levels in the structure exceed permissible levels the slender tubular member is considered to be 'non-redundant', *see* 4.1.4 . This requirement does not apply to stiffened plate structures or mechanical items.

4.1.4 When the requirements of 4.1.3 are not met the intact structure is to be further investigated for loading condition 4.1.2(b) under the action of a 10000 year return period mooring load and associated gravity and functional loads. Non-redundant slender tubular (or similar) members should in general have sufficient ductility to resist failure, i.e., strain up to 21 per cent.
When this criterion is not met the following mitigating measures are required:
(a) clear identification of high stress areas.
(b) welding in high stress areas to be full penetration, as far as practicable.
(c) NDE in accordance with an agreed plan, *see also* Table 9.2.1 in Pt 4, Ch 8.
(d) minimum factor of safety of 2 on fatigue life, *see* Pt 4, Ch 5,5.6.
(e) inspection and test plans (fabrication and in-service) to be submitted for LR approval.
(f) operations manual to clearly specify critical areas and inspection requirements.

4.1.5 The permissible stresses in mooring arms and the attachment to floating units are to comply with Pt 4, Ch 5.

4.1.6 Attention is to be paid to the detail design in fatigue sensitive areas. Mooring arms, towers, articulated and sliding joints are to be assessed for fatigue damage due to cyclic loading in accordance with Pt 4, Ch 5,5.

4.1.7 All structures are to have adequate buckling strength and comply with Pt 4, Ch 5. Special attention is to be paid to the torsional buckling of mooring arms and design calculations are to be submitted.

4.1.8 Mooring towers are to be designed in accordance with an internationally recognised Code or Standard, *see* Appendix A.

4.1.9 Mechanical items and bearings are to comply with Section 6.

4.1.10 Foundations to mooring towers are to comply with the requirements of Chapter 14.

4.1.11 If a classed unit is attached to a mooring tower which is not classed by LR, the mooring tower and its foundations are to be certified by LR or another acceptable organisation, *see* Pt 1, Ch 2,2.1.2.

■ *Section 5* **Mooring hawsers and load monitoring**

5.1 Mooring hawsers

5.1.1 Mooring hawsers permanently attached to a classed installation and used to moor a shuttle tanker, or other ship/unit are included in the classification.

5.1.2 Mooring hawsers are to be of suitable material and construction for the intended service and are to be fitted with:
(a) a chafe chain assembly in accordance with Oil Companies International Marine Forum (OCIMF) *Recommendations for Equipment Employed in the Mooring of Ships at Single Point Moorings*, or equivalent; and
(b) a pick-up line to facilitate the picking up of the hawser by the ship/unit.

5.1.3 Testing and manufacturing inspections of ropes for mooring hawsers are to be in accordance with the following OCIMF Standards, or suitable alternative recognised National or International Standards:
- *Prototype Rope Testing.*
- *Procedures for Quality Control and Inspection during the Production of Hawsers.*

5.1.4 A single-point mooring hawser is to have a minimum rated strength of twice the maximum mooring load, *see* 5.1.5. In the case of a double mooring hawser comprising two individual ropes running to well separated fairleads, each hawser is to have a minimum rated strength of 1,5 times the total maximum mooring load. For classification purposes, the rated strength of a single-point mooring hawser is to be taken as the 'New Wet Break Strength' (NWBS) of the particular hawser assembly, as defined in OCIMF Standards referenced in 5.1.3.

5.1.5 The maximum mooring load used to determine the required strength of a mooring hawser will also be regarded as the maximum allowable peak mooring load in service. This allowable load will be included in the limiting design criteria on which classification is based.

5.2 Load monitoring

5.2.1 Single-point mooring (SPM) installations are to be provided with an approved means of monitoring the load occurring in the mooring hawser connecting the SPM to the ship/unit (alternatively such equipment can be provided on the attending vessel, *see* Pt 7, Ch 6,3 of the Rules for Ships). This equipment is to be designed so that automatic warning is given to the ship/unit in the event that tension in the mooring hawser exceeds designated limits, *see* 5.1.5. Warning is to be given by both visual indication and audible alarm. Consideration will be given to alternative proposals such as provision of a 'weak link'. Full details of such proposals are to be submitted for LR approval.

5.2.2 The load level designated to initiate automatic warning is to be below the maximum allowable hawser load level by a sufficient margin to allow such steps to be taken as may be necessary, to prevent excessive loads, or to prepare for ship/unit disconnection from the SPM. It is recommended that two warning levels be incorporated, the first level at 60 per cent of allowable load and the second level at 80 per cent of allowable load. Where only one warning level is provided it should be set at no more than 70 per cent of allowable load.

5.2.3 The load level designated to initiate the automatic warning should be set giving due consideration to the safe working load of the chain stoppers fitted to the attending vessel.

5.3 Spare parts and maintenance

5.3.1 An adequate number of spare parts for the hawser system is to be provided on board a classed unit.

5.3.2 A planned maintenance and replacement scheme for mooring hawsers are to be submitted to LR and suitable instructions are to be included in the Operations Manual.

■ *Section 6* Mechanical items

6.1 General

6.1.1 In general all machinery, control and electrical items are to comply with the requirements of the appropriate sections in Parts 5 and 6. For pressure vessels, *see* Ch 8,4.

6.1.2 This Section covers mechanical items of turrets and swivels including bearings, hinges, universal joints and seals, etc. Turret structures are to comply with Section 3.

6.1.3 Sufficient plans, data and specifications are to be submitted to enable the mechanical arrangements to be assessed and approved.

6.1.4 Plans and data covering the following items are to be submitted for approval, as relevant:
- Structural arrangements.
- Materials specification.
- Lubrication system.

6.1.5 The following supporting plans and documents are to be submitted:
- General arrangement.
- Design specification.
- Design calculations.
- Surveillance program.

6.2 Design

6.2.1 The design of joint and hinges should minimise any stress concentrations, particularly where significant dynamic loadings may occur.

6.2.2 Suitable strength and fatigue analyses of joint or hinge assemblies are to be carried out, where appropriate.

6.2.3 It is to be considered that vibration levels in the associated pipe work and structure of the swivel are to be kept to a minimum level to avoid bearing-associated failures.

6.3 Bearings

6.3.1 Components in swivel support systems are to be designed for the operating forces, moments and pressures intended, taking into account, where necessary, survival, tow out, damaged, fatigue and other operating conditions. Design calculations are to be submitted.

6.3.2 Rolling element, pad and journal bearings used in swivel units are to be designed for the static and dynamic loadings which are expected in service. Bearing pressure and fatigue life calculations are to be submitted.

6.3.3 Bearings, joints, etc., are to be suitable to withstand the application of all loads expected during service life. The effect of construction tolerances of the bearing and bearing supports is to be considered. The maximum tolerances recommended by the bearing supplier should be used. The maximum design loadings are to be determined in accordance with Pt 4, Ch 3,4.

6.3.4 The design of bearings, joints, etc., is to be in accordance with an acceptable design method or an internationally recognised Code or Standard. For acceptable Codes for roller and ball bearings, *see* Appendix A.

6.3.5 Bearing design is to include the effects of low and high frequency response loadings, where appropriate.

6.3.6 The effects of motions, for a range of typical operating modes, are to be considered in the design.

6.3.7 Where necessary, suitable lubricating arrangements are to be fitted to all adjacent bearing surfaces to maintain an adequate and continuous supply of lubricant to the surfaces during all unattended periods. Gravity-fed or non-power-operated systems are to be preferred for non-manned installations.

6.3.8 Consideration is to be given to monitoring turret roller bearings in service by condition monitoring the bearing lubrication fluid. Details to be submitted to LR.

6.3.9 Primary bearing surfaces are to be adequately protected from deterioration caused by the ingress of sea-water and other contaminants by a system of seals or other suitable alternative methods. Sealing arrangements for bearing systems are to contain lubrication and are to be designed for their intended service life or field life of the installation as applicable.

6.3.10 Data should be submitted to substantiate the fitness of the bearing for the field life of the installation or 20 years, whichever is greater. Consideration will be given to the reduction of this life where an agreed change-out programme is implemented.

6.3.11 Classification will be based on a review of the designers calculations.

6.3.12 In all cases where the bearing dynamic load is more than 50 per cent of the basic load dynamic rating, supporting justification is to be submitted.

6.3.13 The suitability of bearings selected for heavily loaded applications should be checked to ensure that their basic static load rating is adequate, taking into account their static safety factor.

6.3.14 Consideration is to be given to the use of lubricants with EP additives where the bearing loads are high.

6.3.15 Consideration is to be given to rolling element bearings; those which cannot be replaced whilst vessel/buoys are at location are to be designed for L5 bearing life.

6.3.16 Consideration is to be given to ensuring that excessive lubrication is avoided in tilting pad bearings and that the Pressure Velocity is within the recommended limits. For acceptable limits, *see* Appendix A.

6.3.17 Where grease lubrication is being used on a loading buoy bearing, frequent grease sampling and system monitoring are to be considered

6.4 Bearing support structures

6.4.1 Bearing support structures are to be assessed for fatigue damage due to cyclic loading in accordance with Pt 4, Ch 5,5.

6.4.2 Permissible stress levels in supporting structure are to be in accordance with those specified in Pt 4, Ch 5.

6.4.3 A fatigue analysis of structural items is to be carried out in accordance with Pt 4, Ch 5,5. Factors of safety on fatigue life is to be determined after consideration of the redundancy of the structure, the accessibility of the item being considered, the consequence of failure, etc. Minimum required factors of safety are given in Pt 4, Ch 5,5.

6.4.4 Consideration is to be given to improve bearing support structure stiffness to prevent substantial increase in the bearing loading.

6.4.5 Consideration is to be given to the integrity of the weld attachments for the support structures.

6.4.6 Cracking of bearing housings at stress concentrators due to bearing wear is common in roller bearings and should be considered as a potential damage mechanism.

6.4.7 The strength and fatigue analysis of bearing supports is to consider the effect of construction tolerances of the bearing and bearing supports. The maximum tolerances recommended by the bearing supplier should be used.

6.5 Seals

6.5.1 Leakage of lubrication fluid and subsequent ingress of sea-water is to be prevented by installing a suitable system of seals.

6.5.2 The seals employed are to be of a suitable material for the intended service.

6.5.3 Sealing elements installed are to be capable of safely absorbing the required deflection or, alternatively, adequate provisions for slippage are to be incorporated in the design.

6.5.4 A lubrication leakage detection system is to be installed in order to monitor seal performance in service. The system is to provide early warning of seal deterioration to allow appropriate remedial action to be taken.

6.5.5 Swivels and sections in the swivel stack are to use seal arrangements which shall provide redundancy such that leaks can be detected before process fluid release occurs.

6.5.6 The seal fluid pressure is to be higher than the maximum well shut-in pressure and system surge pressure.

6.5.7 A continuous seal fluid leakage detection system is to be monitored to verify system availability and ensure hydrocarbons are not released. The system is to be fitted with alarms to detect early seal deterioration and allow appropriate remedial action to be taken.

6.5.8 In the event of a secondary seal failure, a production ESD is to be initiated and the leak detection system must be capable of precisely identifying the failed seal.

6.5.9 The supply of barrier seal oil for the swivel stack is to be from a dedicated HPU package with its own control panel and feedback to the main control room.

6.5.10 The seal seats and travelling surfaces should be corrosion-resistant and of sufficient hardness to prevent excessive abrasion and wear.

6.5.11 Care is to be taken to minimise the risk of explosive decompression of seal in the event of a catastrophic failure. Maximum decompression rates for the seal material are to be provided by the manufacturer.

6.5.12 Prevention of contamination to dynamic seals is crucial. Seals are to be fitted with a silt-barrier system to prevent sand or particles getting into the seals, where applicable.

6.6 Bolted joints

6.6.1 An acceptable method for the determination of flanged bolt loads is to be found in *Verein Deutscher Ingenieure (VDI) 2230 – Systematic Calculation of High Duty Bolted Joints*. Other suitable internationally recognised Codes or Standards may be used.

6.6.2 For joints subject to fatigue loading, the bolts are to be of ISO 898/1 Material Grade 8.8, 10.9 or 12.9, or equivalent. They are to be pretensioned by a controlled means to 70 to 90 per cent of their yield stress. For bolt sizes greater than M30, pre-tensioning must be carried out, in a rational order, by a hydraulic tensioning device.

6.6.3 The torque on all bolting on bearing housing, support structures and attachments is to be regularly inspected and checked. The maintenance plan is to be submitted to LR for review.

6.7 Swivel stack

6.7.1 The swivel stack is to be designed for the maximum combined operating forces, moments, internal pressures and thermal loading.

6.7.2 In general, the swivel stack is to be analysed by a three-dimensional finite element method unless agreed otherwise with LR. Design calculations, including details of the model, are to be submitted.

6.7.3 Permissible stress levels are to be in accordance with a recognised Code or standard.

6.7.4 Pressure piping attached to the swivel is to comply with Section 7.

6.7.5 Special consideration is to be given to torsional loading effects for the design of universal joints and other connections.

6.7.6 The fluid swivel is to be designed to withstand the maximum range of operating conditions, including maximum well shut-in pressure and pressure surge condition.

6.7.7 Torque arms are to be designed to the appropriate load cases in accordance with Pt 4, Ch 3.

6.8 Survey

6.8.1 Joint structures are to be included in the Periodical Classification Surveys, in accordance with the requirements contained in Part 1.

6.8.2 A comprehensive surveillance program, including detailed seal replacement and overhaul procedures, is to be developed by the Owner. A sufficient number of spare parts and required tools is to be provided for the installation.

■ *Section 7*
Piping and piping systems

7.1 Plans and particulars

7.1.1 Plans and particulars showing arrangement of oil and gas transport systems, marine machinery and piping for equipment listed in 1.5, are to be submitted in triplicate for approval.

7.2 General requirements for piping systems

7.2.1 Pipes, valves and fittings are to be constructed of steel or other approved materials suitable for the intended service. Where applicable, the materials are to comply with the requirements of Pt 5, Ch 12, or an acceptable Standard or Code.

7.2.2 Piping systems for the oil storage or process transport systems are, in general, to be separate and distinct from marine and utility piping systems essential to the safety of the unit. Substances which are known to present a hazard due to a reaction when mixed are to be kept entirely separate.

7.2.3 The oil process transport piping systems, piping and fittings forming parts of such systems are to comply with Chapter 8. For units with oil storage tanks, the requirements of Pt 5, Ch 15 are applicable.

7.2.4 The marine and utility piping systems, piping and fittings forming parts of such systems are to comply with Pt 5, Chapters 12, 13, 14 and 15, as applicable.

7.2.5 Loading and discharging hoses are to be designed in accordance with acceptable recognised Standards. The selected hose is to be designed and constructed such that it is suitable for its intended purpose, taking into account pressure, temperature, fluid compatibility and mechanical loading, *see also* Pt 5, Ch 15,3.4 of the Rules for Ships.

7.2.6 Instrument control isolation valves are to be in the locked open position.

7.2.7 Flexible hoses are to comply with the requirements of Pt 5, Ch 11,7 of the Rules for Ships.

7.2.8 Where valves of the piping systems are arranged for remote control and are power-operated, a secondary means of operating the valves is to be considered.

7.2.9 Watertight compartments are to be provided with power pump suctions for dealing with their drainage. Special attention is to be given to compartments containing equipment which is essential to the safe operation of the installation. The drainage systems are to comply with the requirements of Pt 5, Ch 12.

■ *Section 8*
Hazardous areas and ventilation

8.1 Plans and particulars

8.1.1 Plans and particulars showing the arrangements of area classification and ventilation systems applicable to the control of hazardous area are to be submitted for approval, as required by Pt 7, Ch 2.

8.2 General

8.2.1 For the application of hazardous area classification, *see* Pt 7, Ch 2.

8.2.2 Adequate ventilation is to be provided for all areas and enclosed compartments associated with hazardous fluids. The capacities of the ventilation systems are to comply, where applicable, with the requirements of Pt 7, Ch 2,6, or to an acceptable Code or Standard adapted to suit the marine environment and taking into account any additional requirements which may be necessary during start up of the plant.

■ *Section 9*
Pollution prevention

9.1 General

9.1.1 Sumps and savealls are to be provided at potential spillage points, and drainage systems are to have adequate capacity and be designed for ease of cleaning.

9.1.2 In open areas, arrangements are to be such that oil spillage will be contained, and that suitable drainage and recovery provisions are made that comply with the requirements of National Administration Regulations and any International Convention in force.

■ *Section 10*
Swivel testing requirements

10.1 General

10.1.1 Testing procedure should be specified (and agreed with the Owner/Operator) to ensure that casting, forgings and other items used in the fabrication of the fluid swivel system housing are in accordance with the Rules for Materials.

10.1.2 Seal designs and materials should be Type Approved by dynamic test which simulates a number of years of service under the conditions and with exposure to fluid representative of the design condition and depressurisation. The number of years of successful service to be proven by testing should be agreed with the Owner/Operator.

10.1.3 The following tests are to be performed on each swivel; however, test procedures should be developed by the manufacturers and approved by the Owner/Operator:
(a) Hydrostatic proof test.
(b) Pressure fluctuation test.
(c) Rapid decompression test (Gas Swivel).
(d) Cyclical loading test.

10.1.4 Full rotation tests in each direction and cyclic partial rotation tests should be performed at all operating pressures. Rotation speeds should model real-time conditions to represent accurately the intended application and also to prevent damage to the seals.

10.1.5 Testing is to be conducted in accordance with an approved test procedure in the presence of a Surveyor. The procedure is to address an acceptable leakage rate.

■ *Section 1* General

1.1 Introduction

1.1.1 This Chapter covers the foundations aspects of drag pile, suction pile and gravity anchor points. Where alternative approaches to the recommendations given in Sections 3, 5 and 7 have been used Lloyd's Register (hereinafter referred to as 'LR') may require additional consideration to be given to the foundation design.

1.1.2 Other types of anchor point foundations will be specially considered, as will those supported on permafrost or ice.

1.2 Site investigation

1.2.1 The anchor point foundations design is to be based on the geotechnical conditions found at the actual site.

1.2.2 Sufficient appropriate laboratory and *in situ* tests are to be performed in order to determine the strength and deformation characteristics of the strata underlying the sea bed, and a full report of all tests is to be submitted for approval, *see* Sections 2 and 3.

1.3 Stability of sloping sea beds

1.3.1 Where the anchor point is located on or near a slope, the influence of slope failure due to wave or possible earthquake loading on the anchor point is to be investigated. In particular, consideration is to be given to the influence of increased loading due to slope failures and flow slides.

1.3.2 The results of any calculations or tests are to be submitted.

1.4 Anchor point movements

1.4.1 Estimated values of anchor point movements are to be submitted together with the basis and details of the calculations made.

1.4.2 The anchor points are to be so designed that their movements remain within tolerable limits.

1.5 Earthquake loading

1.5.1 Where appropriate, the influence of earthquake loading on anchor point stability is to be fully accounted for in the design in relation to the particular site conditions.

■ *Section 2* Site investigation

2.1 Extent of investigation

2.1.1 Site investigation data and laboratory testing results are to be submitted to LR to enable the Surveyors to satisfy themselves with regard to:
- sea bed topography;
- nature and stability of the sea bed surface; and
- geomorphology and engineering properties of the strata underlying the sea bed.

2.1.2 The extent of investigations is to be sufficient in area, depth and detail to cover adequately the foundation design. The size and complexity of the proposed anchor point arrangements and the anticipated sea bed soil conditions to be encountered at the anchor point locations are to be considered in determining the extent.

2.2 Methods of investigation

2.2.1 The site investigation is to include combinations of the following methods, where appropriate:
- Detailed bathymetric and side-scan sonar surveys.
- Shallow seismic reflection surveys.
- Shallow sea bed sampling.
- Borehole sampling.
- Shallow and deep *in situ* cone penetrometer testing.
- *In situ* testing such as remote vane, radioactive borehole logging, pressure meter and other proven methods.

Alternative methods may be considered acceptable with the agreement of LR.

2.2.2 The methods of investigation are to be adequate to give reliable information on the following:

- Sea bed topography in sufficient detail for the type of anchor point being installed.
- Presence of sand waves.
- Surface deposits, rock outcrops and debris.
- Variations in subgrade conditions at the anchor point locations.
- Stability of sloping sea beds.
- Natural eruptions and erosion of the sea bed due to emissions of gas, mud, fresh water springs, etc.
- Presence of shallow gas.

■ *Section 3*
Guidelines for site investigation

3.1 Location control

3.1.1 Detailed location and delineation of an area to be investigated is to be by a system accurate to within ±10 m relative to known markers. The subsequent positioning of the anchor point at the selected site must be properly related to the location of the site investigation.

3.2 Bathymetric survey

3.2.1 A bathymetric survey is generally to be performed over an area centred on the proposed floating installation location using an echo sounder and side-scan sonar. The number and spacing of survey lines are to be appropriate to the site characteristics and type and number of anchor points.

3.2.2 The side-scan sonar system is used to map underwater surface features such as rock outcrops, boulders, wrecks, sand waves, pipelines, etc. Where bathymetric and geophysical studies are used as a means of site selection, a wider coverage would be necessary. In such a case the spacing of survey lines may be increased.

3.3 Geophysical survey

3.3.1 Seismic reflection survey measurements should be made concurrently with the bathymetric soundings and side-scan sonar survey. The most suitable seismic profiling system for the site conditions encountered is to be adopted.

3.3.2 Other geophysical studies may be adopted in addition to the seismic reflection survey if thought to be appropriate.

3.4 Observation at the sea bed

3.4.1 The bathymetric survey can be complemented by obtaining soil samples from the sea bed surface. These samples may be obtained with a gravity drop sampler, 'vibrocore' or equivalent system.

3.4.2 Television camera surveys of the sea bed are to be performed at the proposed anchor point locations immediately prior to installation.

3.5 Preliminary geological appraisal of site

3.5.1 Detailed geological information regarding the upper layers of soil and rock may not exist in some offshore areas. In these areas this information will normally have to be gathered from the site investigation sampling programme, *see* 3.11.

3.5.2 In offshore areas where detailed geological data already exist, this information is to be obtained and used to aid determination of the scope and method of site study.

3.6 Scope of borehole sampling

3.6.1 A minimum of one exploration borehole is to be made at each anchor point location.

3.6.2 Where site conditions are geotechnically uniform, a lesser number of exploration boreholes may be justified at an anchor point cluster.

3.6.3 For drag anchors, borings are to extend to a depth greater than the maximum anticipated depth of penetration of the drag anchor. For anchor piles and suction anchor piles, borings are to extend to a depth greater than the maximum anticipated depth of influence of the proposed anchor pile. For gravity anchors, at least one boring is to extend to a depth greater than the maximum anticipated lateral dimension of the proposed gravity base.

3.6.4 Sufficient samples are to be taken in each boring to define adequately soil stratification and properties.

3.6.5 In general, a more detailed investigation of the upper soils immediately below the sea bed is to be carried out for gravity anchors. This may include shallow borings and/or surface cone penetration tests over the proposed location of the foundation, in addition to the boreholes referred to in 3.6.1.

3.6.6 Particular attention is to be given to identifying any thin weak strata which may be critical to the sliding stability of gravity anchors, but of relatively little significance to the design of friction piles.

3.6.7 Careful depth control is to be exercised for all *in situ* testing and sampling.

3.6.8 Records are to be kept of drilling parameters.

3.7 *In situ* testing

3.7.1 Calibrations of *in situ* test apparatus are to be made, and records of these are to be available to LR on request.

3.7.2 Correlation of such techniques as the cone penetration test is to be made by alternating sampling and cone penetration testing in the same borehole. Alternatively, the correlation could be made by performing the *in situ* testing in a borehole immediately adjacent to the sampling borehole.

3.7.3 For drag anchors, shallow cone penetration tests are to extend to a depth greater than the maximum anticipated depth of penetration of the drag anchor.

3.8 Sampling

3.8.1 All sampled material, both disturbed and undisturbed, is to be retained for inspection and testing.

3.8.2 The largest size of sample possible is to be employed, within the limitations imposed by the dimensions of the drilling equipment.

3.8.3 Samples of nominal 70 to 75 mm diameter are a preferred minimum.

3.8.4 Detailed records of each sampling process are to be made which are to include estimates of resistance to penetration (e.g., blow count of drop hammer) and comments on any problems encountered during sampling. These records, together with the preliminary sample description, are to be attached to subsequent descriptions and laboratory test reports for the sample.

3.8.5 In general, pushed samples are preferred to driven samples in cohesive soils and carbonate soils.

3.8.6 Where a wire-line hammer sampler is employed, the depth of each sample is to be checked by measuring the wire-line length.

3.9 Sample storage

3.9.1 For undisturbed samples intended for onshore laboratory testing, consideration is to be given to retaining these sealed in the sample tube under pressure representative of the computed *in situ* stress condition. However, in general, it is acceptable to extrude samples and seal them in wax.

3.9.2 Where suitable facilities exist, as much testing as possible is to be performed offshore.

3.9.3 Strength and deformation tests are to be performed on a proportion of the sample immediately following sample extrusion, *see* 3.12. However, where limited onboard testing facilities exist, samples which cannot be tested immediately are to be placed directly in storage as described above.

3.9.4 All samples are to be labelled in such a way that it is possible to establish the precise order and position of the sample in the borehole. Where a sample is sufficiently large (greater than 50 mm long) and can be distinguished as having a top and bottom, relative to its orientation in the borehole, the sample is to be stored in that orientation and marked as such.

3.10 Sample description

3.10.1 It is most important to establish an accurate and detailed description of each sample. Firstly, in the field, immediately before testing and then again in the onshore laboratory. This practice is worthwhile since significant changes in colour, structure or physical behaviour may be observed to have taken place in the period from the time of sample collection to full extrusion in the laboratory. The latter phase of description, in the onshore laboratory, is to include, where appropriate, a detailed geological description of vertically split sections of the samples. Points which are to be covered by the sample descriptions are detailed in 3.10.2 to 3.10.6.

3.10.2 **Colour**:
(a) The natural colour of the soil is to be recorded immediately following extraction from the borehole.
(b) A colour check of all samples is to be made in the offshore laboratory, when the samples are being prepared for testing. Standard colour charts are to be used and a record made of any observed colour changes.

3.10.3 **Consistency**:
(a) A written description of the hardness of the sample, based on its resistance to sampling and its cone resistance, is to be made in the field.
(b) For cohesive soils, the shear strength ranges pertaining to the terms soft, firm, stiff, hard, etc., are to be defined.
(c) Suitable aids for consistent estimation of shear strength in cohesive soils are the pocket penetrometer and miniature vane tests, which are to be employed whenever possible.
(d) More accurate determination of consistency and stress/strain characteristics will evolve from element tests. Any major difference is to be identified since there may be a real physical change due to sample ageing or other phenomena, such as the influence of natural fissuring.

3.10.4 **Structure**:
(a) The existence of joints, fissures, stratification change, laminations, organic fragments, erratics, or shells, together with their dimensions and frequency, are to be recorded in the sample description.
(b) Structural description of the samples is to be carried out both in the field immediately following extrusion, and in the onshore laboratory. Noticeable changes of structural description such as increased fissure size or shattering are to be recorded.

3.10.5 **Grain size and index properties**:

(a) Grain size is to be determined by standard laboratory tests (sieve and hydrometer analyses).

(b) Care is to be taken to observe (and record) fine layers and beds of different grain size which may significantly alter the grain size distribution of a laboratory specimen.

(c) Where finely laminated materials are encountered, emphasis is to be placed on the visual description of undisturbed specimens.

(d) For fine grained soils, Atterberg limits and natural moisture content are to be determined for all samples.

3.10.6 Odours due to the presence of gas or organic material are to be recorded.

3.10.7 Colour photography is to be used wherever possible to aid description. Although use may be made of photographic techniques in the onshore laboratory, photographs of samples showing their condition immediately following extraction may be made, where their existence can add to the description of the specimen. It is recognised that true colour rendering is difficult. Therefore, a colour chart is to be included in all colour photographs.

3.10.8 Photographs of samples made on board are likely to be taken under far from ideal conditions. Therefore, they are to be confined to recording sample condition immediately following extrusion and, after compression testing, to show failure mode.

3.10.9 Representative samples and parts of samples not utilised as test specimens may be split and photographed with colour film, partially dried and re-photographed.

3.10.10 Sample descriptions for all samples are to be included in the soil laboratory report.

3.11 Geological interpretation of cores and soil samples

3.11.1 The actions in 3.11.2 to 3.11.6 may be reduced or eliminated if they repeat work carried out, or to be carried out, in seismic survey programmes.

3.11.2 Having maintained the cores and soil samples in their correct geological sequence as recommended, *see* 3.9, a detailed geological interpretation of the log of the borehole may be made.

3.11.3 The geological description of the borehole is to be made by a qualified geologist.

3.11.4 The geologist is to examine the partially dried split sections of the cores and soil samples, if available, and extract appropriate specimens for laboratory testing. The testing programme assigned by the geologist, however, is to be additional to that required by the soil mechanics engineer.

3.11.5 The results of the geological test programme are to be considered only as supporting data, by means of which a better definition of the site stratigraphy and stress history can be determined. Where relatively small amounts of sampled material exist it may be necessary for the geological tests to be performed on the remains of specimens which have already undergone engineering tests.

3.11.6 The geological testing programme may generally be restricted to techniques such as:

- Comparison of grain size distributions as a means of determining deposition history.
- Detailed examination of interglacial deposits where they are found.
- Identification of erratics.
- Simple chemical tests.
- Simple mineralogy.
- Pollen analysis and micropalaeontological examination.

3.12 Onboard testing

3.12.1 The ability to perform engineering tests on undisturbed samples of soil immediately after they are extracted from the borehole is to be considered an ideal practice.

3.12.2 Simple onboard tests are to include the following:

(a) Hand penetrometer and vane tests on the exposed ends and sides of undisturbed samples of cohesive soils. Results of such tests are only to be considered as an approximate index of strength. Any evidence of anisotropy is to be noted. The hand vane test may also be performed on remoulded samples of cohesive soil as a means of determining sensitivity.

(b) Fall-cone test on samples of soft cohesive material as a means of estimating undrained shear strength.

(c) Natural moisture content and density determinations.

3.12.3 Where more sophisticated laboratory facilities exist on board, the following additional tests may be performed:

(a) Triaxial compression tests. A sketch, or preferably a photograph, of the failed specimen is to be made, and be attached to the test report.

(b) Consolidation (oedometer) tests, preferably at a constant rate of strain. Such tests might be carried out to determine preconsolidation pressures and consolidation characteristics of samples of cohesive soil.

3.12.4 In addition to the above onboard testing, a full programme of onshore laboratory tests as recommended in 3.13 to 3.19 are to be performed.

3.13 Laboratory index tests

3.13.1 The following index tests are to be performed on a representative number of specimens throughout the soil profile:

- Natural moisture content and density determination.
- Atterberg limit tests on all cohesive samples.
- Grain size distribution using both sieves and hydrometer.

3.14 Shear strength parameter determination – Cohesive soils

3.14.1 Hand penetrometer and vane tests are to be performed in the laboratory, for comparison with onboard measurements. Any significant change in strength is to be noted.

3.14.2 Laboratory penetrometers and fall cones (for soft soils) may also be employed as a means of determining undrained shear strength of small samples.

3.14.3 Quick unconsolidated undrained and quick consolidated undrained triaxial compression tests are to be performed, with cell pressures equal to or greater than the computed overburden pressure of the specimen.

3.14.4 Effective stress parameters of cohesive soil are to be determined where applicable, using either consolidated undrained triaxial compression tests with pore pressure measurement, or drained triaxial compression tests. Where only a limited number of samples are available, multi-stage consolidated undrained tests with pore pressure measurement may be adopted.

3.14.5 It is to be noted that current practice is to use unconsolidated undrained triaxial tests as the basis of shear strength parameter determination for analysis of piles in cohesive soils, and it is therefore vital that sufficient of these tests are performed to define adequately the shear strength variation with depth.

3.14.6 For gravity anchor foundations, consideration is to be given to performing a wide range of tests which take account of the shearing mechanism expected to occur at various locations within the soil beneath the foundation.

3.15 Shear strength parameter determination – Cohesionless soils

3.15.1 Drained or consolidated undrained triaxial compression tests and shear box tests may be used to determine the shear strength parameters of sands. These tests are to be performed over a range of relative densities for each sand specimen, since the sampling process will lead to significant disturbance.

3.15.2 In general, shear strength parameters for use in design of piles in cohesionless soils are to be determined on the basis of cone penetration tests and sample descriptions.

3.15.3 For gravity anchor foundations, consideration is to be given to performing a wide range of tests which take account of the shearing mechanism expected to occur at various locations within the soil beneath the foundation.

3.16 Special shear strength determination tests

3.16.1 Consideration is to be given to performing tests which will provide some estimate of the present *in situ* stress condition and anisotropy.

3.16.2 Special element tests to examine the influence of cyclic loading may be performed on soil specimens where appropriate. The result of these tests, however, are to be treated with extreme caution when they are used to predict the performance of the full scale foundation.

3.17 Consolidation characteristics

3.17.1 It is unlikely that large samples (150 mm diameter) will be obtained from the average offshore site investigation. Therefore, consolidation characteristics may be measured by the standard oedometer test.

3.17.2 Care is to be taken to avoid swelling on introduction of water into the cell at low stress levels.

3.17.3 Preconsolidation pressure and coefficients of compressibility may be determined directly from the test.

3.17.4 The rate of consolidation is to be estimated, having regard to the detailed sample description and the permeability of the fabric, since rates of consolidation measured in a small oedometer test are likely to be misleading.

3.18 Chemical tests

3.18.1 The chemical properties of the soil and soil pore water are to be established where appropriate. The following properties are to be determined:
- Chloride (salt) content.
- Sulphate content.
- pH.
- Carbonate content.

3.19 Permeability

3.19.1 Estimates of permeability may be based on grain size distribution for sandy soils.

■ *Section 4* Drag anchors

4.1 Drag anchor design

4.1.1 The drag anchor design is to be approved by LR and the anchors are to be subject to test loading at installation to the satisfaction of LR Surveyors, *see* Chapter 10.

4.2 Ultimate holding capacity, penetration and drag

4.2.1 For drag anchors, the ultimate holding capacity, penetration and drag are to be based on empirical design data for the specific type of anchor under consideration. The soil conditions at the anchor location and previous experience in similar soil conditions with the specific type of anchor are to be considered.

4.2.2 Particular consideration is to be given to locations with layered soil conditions and their effect on ultimate holding capacity, penetration and drag.

4.2.3 The use of analytical design methods to predict drag anchor holding capacity, penetration and drag will be considered as a supplement to 4.2.1, provided that the methods have been calibrated to actual anchor behaviour.

4.2.4 The use of centrifuge testing of model drag anchors will be considered as a supplement to 4.2.1.

■ *Section 5*
Anchor and suction anchor piles

5.1 Anchor and suction anchor pile design

5.1.1 The anchor and suction anchor pile designs are to be approved by LR.

5.2 Axial and lateral capacity

5.2.1 The pile penetrations are to be determined by their ability to develop sufficient axial, tensile (and compressive) and lateral capacity to resist the maximum applied loads with appropriate factors of safety.

5.2.2 The minimum factors of safety for anchor piles are to comply with Tables 10.10.2 and 10.10.3, and for suction anchor piles with Tables 10.10.4 and 10.10.5, in Chapter 10.

5.2.3 Consideration is to be given to cyclic loading effects on pile axial and lateral capacity.

5.2.4 For anchor pile clusters, the group as a whole is to have a factor of safety as required by Table 10.10.2 and Table 10.10.3 in Chapter 10. Individual anchor piles in a group may have lower factors of safety.

5.2.5 The efficiency of the group, that is its capacity compared to the sum of the capacities of individual anchor piles within the group, is to be checked.

5.3 Anchor and suction anchor pile response

5.3.1 Analysis of the anchor and suction anchor pile/soil interaction under lateral and axial loading is to take account of the non-linear stress/strain behaviour of the foundation soils and of stress history and cyclic loading effects on soil resistance. Allowance is to be made for the response of different soil types.

5.3.2 When anchor pile groups are analysed the interaction between the piles is to be considered.

5.3.3 Anchor and suction anchor pile stresses are to be checked for extreme, operating and installation loading conditions in accordance with Pt 4, Ch 3, or a recognised structural design Code.

5.3.4 Pile deflections and rotations are to remain within tolerable limits.

5.4 Sea bed erosion

5.4.1 Account is to be taken of the effects of both global and local scour in calculations of pile response and axial and lateral capacity.

5.5 Installation – General

5.5.1 Details of the proposed method of installation and its associated monitoring system are to be submitted.

5.5.2 Where possible the placing of the anchor and suction anchor piles is to be monitored using the same positioning system as was used to locate the position of the site survey area, and which is to be accurate to within ±10 m.

5.5.3 Orientation and verticality of the pile during installation are to be recorded.

5.6 Installation of driven anchor piles

5.6.1 Driving stresses and static stresses due to the weight of the hammer are to be considered in the selection of pile driving hammers and pile wall thickness. Driving stresses are also to be included in any assessment of pile fatigue.

5.6.2 Where driving shoes are employed as a means of reducing soil plug friction during pile driving, an equivalent reduction of internal skin friction is to be adopted in the determination of allowable end bearing capacity.

5.6.3 A full record of the anchor pile driving operation is to be kept, and is to be submitted to LR.

5.6.4 The record of anchor pile driving operations to be submitted to LR is to include the following details:

- Timing of the various operations.
- Hammer characteristics.
- Blowcount.
- Configuration of the top of the pile giving the cushion and anvil materials together with salient dimensions.
- State of cushion (number of blows suffered and physical appearance) at the start of driving and time(s) at which cushion is changed.
- Estimates of hammer stroke and any measurements of striking energy and energy transmitted to pile head.
- Soil plug measurement on completion of pile driving.

5.7 Installation of bored anchor piles

5.7.1 The methods for drilling and grouting and details of the plant and materials to be used are to be submitted to LR for approval.

5.7.2 The construction programme is to avoid leaving holes open for long periods in soils or rock sensitive to exposure to water or drilling fluids.

5.7.3 A full record of the drilling and grouting operation is to be submitted to LR.

5.7.4 A specimen record is to be submitted for approval prior to the installation of the first pile.

5.7.5 The record of installation of drilled and grouted anchor piles to be submitted to LR is to include the following details:

- Timing of various operations.
- Method of drilling.
- Density, viscosity, flow rate and pressure of drilling fluid during drilling.
- Description of returns, if any, from the borings.
- Bit pressure, torque and speed of drilling tools.
- Details of circulation loss and any remedies adopted.
- Hole survey details (the profile and linearity of all holes are to be surveyed to their full depth).
- Details of checks made to determine the existence of any material which has fallen into the hole prior to grouting.
- Final position of any reinforcement or insert piles placed.
- Fluid pressure maintained during drilling and grouting.
- Details of the density, flow rate, grout level and pressure of grout during pumping and total volume of grout pumped (means of monitoring should be specified).
- Details of grout mix design and of its constituent materials.
- Programme of grout sampling and testing, including measurements of density and grout crushing strength at 28 days.
- Grout level on completion and after at least 12 hours after completion.

5.8 Suction – Installed anchor piles

5.8.1 The proposed installation procedures are to be submitted to LR for approval.

5.8.2 Appropriate records are to be submitted to LR for approval.

5.8.3 Soil resistance to suction anchor piles is to be determined. The potential for internal soil heave and soil plug failure during installation is to be considered.

5.8.4 The record of installation of piles installed by suction to be submitted to LR is to include:

- pile penetration;
- pressure differential;
- orientation; and
- verticality.

■ *Section 6* Acceptable basis for anchor and suction anchor pile design

6.1 Axial capacity

6.1.1 This Section is for guidance and is not mandatory for classification purposes.

6.1.2 The ultimate pull-out capacity, Q_t, is to be determined from the formula:

$$Q_t = A_s f_s$$

where

A_s = external side surface area in contact with soil
f_s = unit skin friction.

6.1.3 The ultimate bearing capacity, Q_{ult}, may be determined for compression loads by:

$$Q_{ult} = A_s f_s + A_p q_p$$

where

A_p = gross end area of pile in contact with soil
q_p = unit end bearing capacity.

6.1.4 For driven and suction installed open ended piles, end bearing ($A_p q_p$) is not to exceed the capacity of the internal plug, which is given by the sum of the internal skin friction ($A_{si} f_{si}$) and the end bearing on the pile wall,

where

A_{si} = internal surface area of pile in contact with soil
f_{si} = internal unit skin friction, which may differ from f_s, e.g., due to the effect of a driving shoe.

6.1.5 In cohesionless soils (sand and silts) in tension, a reduced value of f_s, as compared with compression loading, is to be adopted.

6.1.6 The effective weight of the pile is also to be accounted for in the analysis. In general, this is to be added to the pile load.

6.2 Skin friction in cohesive soils

6.2.1 The unit skin friction, f_s, for piles driven and suction installed through cohesive soils (clays and silts) may be based on the undrained shear strength of the soil reduced by a constant which is related to the actual undrained shear strength.

$$f_s = \alpha S_u$$

where

S_u = the undrained shear strength of a soil layer
α is an empirical factor.

6.2.2 Values of α are defined according to Table 14.6.1.

6.2.3 It is to be noted that the values given in Table 14.6.1 are based on limited pile load tests with respect to pile diameter, capacity and soil shear strength. In this regard, caution is to be exercised in extrapolating beyond the limits of the data set.

Table 14.6.1 Values of α

S_u (kPa)	α
0 – 25	1,0
25 – 75	linear decrease from unity at S_u = 25 kPa to 0,5 at S_u = 75 kPa
greater than 75	0,5

6.2.4 Other methods of determining f_s may be considered, provided they are supported by sufficient evidence of their validity together with appropriate laboratory and field test results.

6.2.5 For drilled and grouted piles α is, in general, to be taken as 0,4, irrespective of undrained shear strength.

6.3 End bearing in cohesive soils

6.3.1 For anchor piles end bearing in cohesive soils:

$$q_p = N_c S_u$$

where N_c may be taken as 9, in most circumstances, for clays with water contents within the plastic range. N_c may be less than 9 in sensitive clays.

6.3.2 No end bearing is to be taken for drilled and grouted piles unless it can be demonstrated that there is no infill at the bottom of the drilled hole, or the calculations account for the compressibility of such infill.

6.4 Skin friction in cohesionless soils

6.4.1 The unit skin friction, f_s, for piles driven and suction installed through cohesionless soils is to be determined by:

$$f_s = K\sigma'_v \tan\delta$$

where

σ'_v = $\gamma' d$

γ' = mean submerged density of soil to depth d

d = depth of soil element below the mudline

K = coefficient of lateral earth pressure

δ = angle of soil friction on pile wall as determined, in the absence of cone data, by Table 14.6.2, wherein ϕ is the angle of internal friction of soil.

6.4.2 Values of K may be adopted as follows:

(a) Compressive loading, K = 0,7.

(b) Tension loading, K = 0,5.

Alternative values of K may be adopted provided their use can be justified for the particular soil conditions encountered.

6.4.3 The unit skin friction, f_s, is not to exceed limiting values determined for local conditions, based on cone resistances and sample descriptions. These limits are not to be greater than 100 kPa where no cone data is available, or 120 kPa where cone data is available.

6.4.4 For carbonate granular soils, reduced values of unit friction, determined for local conditions, are to be used.

Table 14.6.2 Design criteria for axial capacity of driven piles in medium dense to very dense silica sand

	ϕ (degrees)	δ (degrees)	N_q
Very dense clean sand	40	35	50
Very dense silty sand Dense clean sand	35	30	40
Dense silt sand Medium dense clean sand	30	25	20
Dense silt Medium dense silty sand	25	20	12
Medium dense silt	20	15	8
NOTE The parameters for very loose to loose sand and silt should be specially considered.			

6.5 End bearing in cohesionless soils

6.5.1 For piles end bearing in cohesionless soils, q_p, is to be determined by:

$$q_p = \sigma'_v N_q$$

where

N_q = bearing capacity factor in accordance with Table 14.6.2 in the absence of cone data

σ'_v = $\gamma' d$.

6.5.2 The unit end bearing q_p is not to exceed limiting values determined for local conditions, based on cone resistances and sample descriptions. These limits are not to be greater than 10 MPa, where cone data is not available, or 15 MPa where cone data is available.

6.5.3 No end bearing is to be taken for drilled and grouted piles unless it can be demonstrated that there is no infill at the bottom of the drilled hole, or the calculations account for the compressibility of such infill.

6.6 Skin friction and end bearing in rocks

6.6.1 Skin friction and end bearing in rocks are to be specially considered.

6.7 Axial capacity of pile groups

6.7.1 Consideration is to be given to the effect of close spacing of piles, since the ultimate axial capacity of a group can be less than the sum of the individual capacities.

6.7.2 The calculation of safe loading may be based on consideration of the group as an 'equivalent pier' such that, for compressive loads:

$$Q_g = S\,A_{sg} + q\,A_{pg}$$

where

Q_g = ultimate bearing capacity of the pile group
$S\,A_{sg}$ = the ultimate frictional capacity of a pile group
S = average shearing resistance, soil to pile and soil to soil
A_{sg} = surface area of outer perimeter of pile group if considered as an equivalent pier
q = unit end bearing
A_{pg} = gross end area of piles in group. In order to account for different rates of mobilisation of skin friction and end bearing, $A_{pg} = nA_p$ where n is number of piles in group and A_p is single pile tip area.

Note
For tensile loads, no end bearing (or suction) component is to be considered, and the shearing resistance may be lower, as noted in 5.2.5.

6.7.3 The surface area of soil to pile shear is to be maximised, in order to give the most conservative solution. The group capacity should not exceed the sum of the individual pile capacities.

6.8 Pile response and lateral capacity

6.8.1 For anchor piles, the lateral capacity and pile response are to be determined using either a beam-column non-linear soil/structure interaction finite element analysis or finite difference analysis. The non-linear axial and lateral soil resistance/pile deflection behaviour is to be modelled using t-z and p-y curves, respectively.

6.8.2 For suction anchor piles, the lateral capacity and stability are to be determined using both limit equilibrium and non-linear soil/structure interaction finite element analyses. Pile response and the determination of soil reaction stresses for structural analysis of the suction anchor pile are to be analysed using non-linear soil/structure interaction finite element methods.

6.9 Driving stresses

6.9.1 The stresses induced in the pile during driving can be estimated using a wave equation analysis.

6.9.2 Total stresses during driving are not to exceed yield.

6.9.3 Fatigue damage due to pile driving is to be considered.

■ *Section 7*
Gravity anchors

7.1 Scope

7.1.1 Gravity anchor foundations are to comply with this Section.

7.2 Gravity anchor foundation design

7.2.1 The foundation design is to be approved by LR.

7.2.2 The foundation is to resist the following modes of failure:

- Overturning.
- Bearing.
- Sliding.
- Combinations of the above.

7.2.3 Undrained, partially drained and fully drained soil states are to be considered, as appropriate.

7.2.4 Load conditions considered are to include minimum and maximum imposed loads and load combinations throughout the wave cycle.

7.2.5 Wave loads on the sea bed are to be considered when such loads are unfavourable to stability.

7.2.6 Complete contact with the sea bed is to be maintained at all times and the stresses imposed by the foundations on the sea bed are to be compressive under all loading conditions.

7.3 Foundation movements

7.3.1 Calculations of foundation movements are to include the effects of short-term and long-term loading.

7.3.2 The following possible causes of vertical movements are to be investigated:

- Immediate settlement.
- Secondary settlement due to dead load.
- Long-term consolidation and settlement due to repeated short-term loads and to dead loads.
- Recoverable displacements due to transient loading.

7.3.3 Particular account is to be taken of the possibility of differential settlement due to variations in soil conditions over the foundation base area.

7.3.4 The extent of horizontal movements and tilt are to be assessed. The relative magnitudes of recoverable and non-recoverable displacement are to be determined.

7.4 Influence of cyclic loading

7.4.1 The influence of cyclic loading on the foundation soils is to be investigated and taken into account in the foundation design for:

- Bearing capacity.
- Sliding stability.
- Displacements.
- Erosion.

7.4.2 In making this assessment, full account is to be taken of possible reduction of soil shear strength and changes in deformation properties.

7.4.3 When cohesionless soils of loose and variable density occur, the possibility of soil liquefaction under cyclic loading is to be considered for environmental loading cycles and also for seismic conditions where these may be critical.

7.5 Sea bed erosion

7.5.1 The influence of erosion of soils from around and beneath the foundation is to be taken into account in its design. Erosion due to the following causes is to be investigated:

(a) The effect of waves and currents passing over the sea bed at velocities sufficient to dislodge and transport particles of bed material (scour).

(b) The relief of hydraulic pressures and pore water pressures built up under the foundation due to environmental loading, which may cause the removal of soil from beneath the foundation (sub-surface erosion or piping).

7.5.2 The methods proposed for the prevention of, and/or protection against, erosion are to be submitted for approval. In general, primary protection is to be provided by sea bed-penetrating skirts.

7.5.3 Any erosion protection system laid on the sea bed is to be so designed that it will permit free dispersion of pore water pressures that may be generated in the surface soil under cyclic loading conditions.

7.5.4 Provision is also to be made for the relief of water pressure generated within the skirts during installation of the structure.

7.6 Foundation contact pressure

7.6.1 Calculations of local contact stresses between the foundation and the sea bed are to take into account the results of the sea bed survey.

7.6.2 Unless specifically considered in the design, any voids remaining beneath the foundation after installation are to be filled with, e.g., cementitious grout.

7.7 Sea bed penetrating elements

7.7.1 Where foundations have skirts, dowels or other sea bed-penetrating elements which transfer load to the sea bed, the effect of these components is to be taken into account when determining the efficiency of, and loads in, the foundations for bearing capacity and sliding resistance. These items are to be designed as structural members.

7.7.2 The resistance of skirts, dowels, etc., to penetration of the sea bed during installation of the foundation and their effect, if any, on water flow beneath the foundation during installation is to be taken into account in the design calculations.

7.8 Installation of gravity anchor foundations

7.8.1 The positioning of the foundation is to be properly related to the location of the site investigation.

7.8.2 Any significant obstructions identified by the sea bed survey carried out prior to installation are to be removed before emplacement.

7.8.3 Differential ballasting may be required to accommodate non-uniform soil properties or a sloping sea bed. In general, reduction of pressure beneath the foundation is not to be used to aid installation, unless it can be demonstrated that washout or flow of soil will not occur.

7.8.4 Records of settlement and tilt of the structure are to be made during installation and properly correlated to those required to be kept while the structure is in service.

■ *Section 8*
Acceptable basis for gravity anchor design

8.1 Bearing capacity

8.1.1 Published formulae for calculating the bearing capacity of uniform soils subjected to vertical or inclined loads may be used to assess the stability of gravity foundations assuming equivalent static loading conditions.

8.1.2 A suitable method, described in 8.1.3 to 8.1.9, is based on the following publications:

- Brinch Hansen, J (1961) *A general formula for bearing capacity*, Danish Geotechnical Institute Bulletin 11; and
- Brinch Hansen, J (1970) *A revised and extended formula for bearing capacity*, Danish Geotechnical Institute Bulletin 28.

8.1.3 The bearing capacity of a horizontal base founded on level ground is given, for cohesionless soils, by the equation:

$$\frac{Q}{A'} = 0{,}5\gamma' B' N_\gamma s_\gamma d_\gamma i_\gamma + (\sigma'_v N_q s_q d_q i_q)$$

and for undrained cohesive soils by:

$$\frac{Q}{A'} = N_c S_u + (1 + s_c + d_c - i_c)$$

where

Q = bearing capacity
A' = effective foundation area
γ' = submerged unit weight of soil
B' = effective foundation width
N_γ, N_q, N_c = bearing capacity factors
s_γ, s_q, s_c = shape factors
d_γ, d_q, d_c = depth factors
i_γ, i_q, i_c = load inclination factors
σ'_v = effective overburden pressure
S_u = undrained shear strength.

8.1.4 For loose or soft soils the bearing capacity may be lower than that calculated by the equations in 8.1.3.

8.1.5 The effective foundation area, A', is a rectangular area whose geometric centre coincides with the centre of resultant vertical and horizontal loads and which follows as closely as possible the nearest outline of the actual base. The width of the equivalent rectangle is B' and the length L'.

8.1.6 The bearing capacity factors are defined as follows:

$$N_\gamma = 1{,}5\,(N_q - 1)\tan\phi'$$

$$N_q = e^{\pi\tan\phi'}\tan^2 45° + \left(\frac{\phi'}{2}\right)$$

$$N_c = \pi + 2$$

where ϕ' is the effective angle of friction of the soil, in degrees.

8.1.7 The load inclination factors are given as follows:

$$i_\gamma = \left(1 - 0{,}7\frac{H}{V}\right)^5$$

$$i_q = \left(1 - 0{,}5\frac{H}{V}\right)^5$$

$$i_c = 0{,}5 - 0{,}5\sqrt{1 - \frac{H}{A'S_u}}$$

where

H and V are horizontal and vertical loads respectively.

8.1.8 The shape factors are given as follows:

$$s_\gamma = 1 - 0{,}4 i_\gamma \frac{B'}{L'}$$

$$s_q = 1 + i_q \sin\phi' \frac{B'}{L'}$$

$$s_c = 0{,}2\,(1 - 2i_c)\frac{B'}{L'}$$

8.1.9 The depth factors d_γ and d_q may generally be taken as unity, and d_c as zero.

8.1.10 The formulations from 8.1.2 are strictly only applicable to a foundation bearing on a single, semi-infinite, stratum of isotropic, homogeneous soil. However, real sites incorporating a number of soil strata of different materials or cohesive soils with increasing strength with depth may be assessed using such formulations provided that conservative soil properties are used. Alternative methods of analysis and computer and physical models may also be used to evaluate such soil conditions.

8.2 Sliding stability

8.2.1 The analysis is to consider all possible failure modes in sliding. These may be dependent on the configuration of any sea bed-penetrating elements of the foundation. Particular consideration is to be given to the influence of weak strata or zones.

8.3 Sea bed penetrating elements

8.3.1 The penetration resistance of elements such as skirts and dowels is to be based on conservative (upper bound) estimates of soil strength. Also, by considering more typical penetration resistances, account may be taken of lateral variation of soil conditions over the extent of the foundation in formulating possible eccentric ballasting requirements.

8.4 Local soil reactions

8.4.1 Local soil reactions on gravity foundations are to be based on the highest expected values of soil strength in the upper soil layers.

8.5 Deformations

8.5.1 Deformation analyses may be made using numerical methods or hand calculations.

8.5.2 Account is to be taken of soil stratification and non-linearity, and of uncertainties in soil deformation properties.

8.5.3 Soil stiffnesses may be estimated from laboratory tests or empirical correlations.

■ *Section 1* Integrated Software Intensive System – 'ISIS' notation

1.1 General

1.1.1 Integrated Software Intensive System class notation **ISIS** may be assigned where an integrated computer system in compliance with Pt 6, Ch 1,6 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) provides fault tolerant control and monitoring functions for one or more of the following services:

- Propulsion and auxiliary machinery.
- Dynamic positioning systems.
- Positional mooring systems.
- Ballast systems.
- Process and utilities.
- Drilling equipment.
- Product storage and transfer systems.
- Well control system.
- Pollution control system.
- Jacking system for self-elevating unit.
- Cantilever skidding system for drilling unit.
- Power Management System (PMS).
- Zone Management Systems (ZMS) (for all equipment where applicable).
- Mud and cement management system.

1.2 General requirements

1.2.1 The Integrated Software Intensive System is to comply with the programmable electronic system requirements of Pt 6, Ch 1,2.10 to 2.13 of the Rules for Ships and the control and monitoring requirements of the Rules applicable to a particular equipment, machinery or systems.

1.2.2 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system, *see also* Pt 6, Ch 1,2.14.7 of the Rules for Ships.

1.3 Programmable electronic systems – Additional requirements for integrated systems

1.3.1 The requirements of Pt 6, Ch 1,2.14.2 to 2.14.7 of the Rules for Ships apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or ship safety functions, *see* Pt 6, Ch 2,17 to 19 of the Rules for Ships.

1.3.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and ship safety.

1.3.3 The system requirements specification, *see* Pt 6, Ch 1,1.2.5 of the Rules for Ships, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

1.3.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

1.3.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew, and ship safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see* Pt 6, Ch 1,2.4.6 and 2.5.4 of the Rules for Ships, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

1.3.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

1.3.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g., the selection of a particular screen page or mode of operation. *See also* Pt 6, Ch 1,2.10.16 of the Rules for Ships.

1.4 Operator stations

1.4.1 The requirements for the operator stations are given in Pt 6, Ch 1,6.3 of the Rules for Ships, which are to be complied with.

1.4.2 Additions or amendments to these requirements are given in 6.3.3.

1.4.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g., in control, standby, etc.) is to be clearly indicated, *see also* 2.2.

■ *Section 2*
Systems engineering principles

2.1. General – Scope and objectives

2.1.1 The requirements of this Section aim to ensure that risks to offshore safety and the environment, stemming from the introduction of integrated software intensive systems, are addressed insofar as they affect the objectives of classification. Hereafter, integrated software intensive system includes all systems listed in 1.1.1.

2.1.2 The requirements of this Section are to be satisfied where an integrated software intensive systems is required to be developed, constructed, installed, integrated and tested in accordance with LR's Rules and Regulations and for which the corresponding machinery class notation is to be assigned, *see* Pt 1, Ch 2,2.5.

2.1.3 It is to be noted that as well as the requirements of this Section, the general requirements of LR's Rules and Regulations are also to be satisfied as far as they are applicable.

2.1.4 Compliance with ISO 15288 *Systems and Software Engineering – System Life Cycle Processes* or an acceptable equivalent National Standard may be accepted as meeting the requirements of Pt 6, Ch 1,2.3 to 2.12 of the Rules for Ships.

2.2 Information to be submitted

2.2.1 The information described in 2.2.2 and 2.2.3 is to be submitted for consideration.

2.2.2 General description detailing the extent of the integrated software intensive system, the offshore unit services it is to provide, its operating principles, and its functionality and capability when operating in the environment to which it is likely to be exposed under both normal and foreseeable abnormal conditions. The general description is to be supported by the following information as applicable:

(a) System block diagram.
(b) Piping and instrumentation diagrams, communication networks.
(c) Description of operating modes, including:
start-up;
shut-down;
automatic:
reversionary;
manual, and
emergency.
(d) Description of safety related arrangements, including:
safeguards;
automatic safety systems; and
interfaces with offshore units safety systems.
(e) Description of connections to other offshore unit machinery, equipment and systems, including:
electrical;
mechanical;
fluids;
automation;
communication network; and
protocols of the network.
(f) Plans of physical arrangements, including:
location;
operational access; and
maintenance access.
(g) Operating manuals, including:
instructions for start-up;
operation;
shut-down and emergency;
instructions and frequency for maintenance;
instructions for adjustments to the performance;
parameters and functionality; and
details of risk mitigation arrangements.
(h) Maintenance manuals, including:
Instructions for routine maintenance or repair following failure.
Instructions for software configuration management such as upgrading and modification.
Disposal of components and recommended spares inventory.

2.2.3 Project process documentation including:

(a) Project management plan, *see* 2.3.
(b) Quality assurance plan, *see* 2.4.
(c) Risk management plan, *see* 2.5.
(d) Configuration management plan, *see* 2.6.
(e) Requirements definition document, *see* 2.9.
(f) Design definition document, *see* 2.8.
(g) Implementation plan, *see* 2.9.
(h) Integration plan, *see* 2.10.
(j) Verification plan, *see* 2.11.
(k) Validation plan, certification and survey, *see* 2.12.

2.3 Project management

2.3.1 A project management procedure is to be established in order to define and manage the key project processes. The project processes are to include the those described in Pt 6, Ch 1,2.4 to 2.12 of the Rules for Ships.

2.3.2 For the entire project, and each of the processes within the project, the project management procedure is to define the following:

(a) Activities to be carried out.
(b) Required inputs and outputs.
(c) Roles of key personnel.
(d) Responsibilities of key personnel.
(e) Competence of key personnel.
(f) Schedules for the activities.
(g) Roles and responsibilities of stakeholders including Owner, Operator, Shipyard, System Integrator, Supplier or Subcontractor for each required activity of project processes from 2.3 to 2.12.

2.4 Quality assurance

2.4.1 A quality assurance procedure is to be established in order to ensure that the quality of the integrated software intensive system is in accordance with a defined quality management system that is acceptable to LR.

2.4.2 The procedure is to define the specific quality controls to be applied during the project in order to satisfy the requirements of the quality management system.

2.4.3 The quality management system is to satisfy the requirements of ISO 9001 *Quality management systems.* Requirements and software development is to satisfy the requirements of ISO 90003 *Software engineering – Guidelines for the application of ISO 9001 to computer software*, or other equivalent acceptable National Standard.

2.5 Risk management

2.5.1 A risk management procedure is to be established in order to ensure that any risks stemming from the introduction of the integrated software intensive system are addressed, in particular risks affecting:

(a) The structural strength and integrity of the offshore unit's hull.
(b) The safety of integrated software intensive system onboard of the offshore unit.
(c) The safety of crew.
(d) The reliability of essential and emergency systems.
(e) The environment.
(f) Offshore drilling operations with introduction of integrated software intensive systems.

2.5.2 The procedure is to consider the hazards associated with development, integration, installation, operation, maintenance and disposal, both with the integrated software intensive system functioning correctly and following any reasonably foreseeable failure.

2.5.3 The procedure is to take account of stakeholder requirements, *see* 2.7.

2.5.4 The procedure is to take account of design requirements, *see* 2.8.

2.5.5 The procedure is to ensure that hazards are identified using acceptable and recognised hazard identification techniques, *see* 2.5.9 to 2.5.14, and that the effects of the following influences are considered:

(a) Offshore unit operations, including:
    Underway, manoeuvring, pilotage, docking, alongside and maintenance, jacking or dynamic positioning, well drilling, well completion, well control, training exercises, emergency abandon, commissioning and trials.
(b) Offshore unit conditions under normal and reasonably foreseeable abnormal operating conditions arising from failures or misuse of equipment or systems onboard of offshore unit, including:
    Normal operation, blackout, loss of position, fire in a single compartment, explosion in a single compartment and flooding of a single compartment.
(c) Configuration and modes of operation provided for the intended control of integrated software intensive system, including:
    Start-up, running, shut-down, automatic, reversionary, manual and emergency.
(d) Environmental conditions, including:
    Temperature, pressure, humidity, water spray, salt mist, vibration, shock, inclination, vocanic activities, seabed conditions, hurricane or storm, subsea acoustic noise, electrical fields and magnetic fields.
(e) Dependencies, including:
    Power, fuel, air, cooling, heating, mud, cement, data, and human input.
(f) Environmental impact of the offshore unit throughout its lifecycle, including:
    Emissions to air, discharges to water, noise and waste products.
(g) Failures, including:
    Human error, supply failure, system, software, communication network, machinery, equipment and component failure, random, systematic and common cause failures.

2.5.6 The procedure is to ensure that risks are analysed using acceptable and recognised Risk Based Analysis techniques, *see* 2.5.9 to 2.5.14, and that the following effects are considered:

(a) Local effects: Loss of function, component damage, fire, explosion, electric shock, harmful releases and hazardous releases.
(b) End effects on: Loss of services essential to the safety of the offshore unit, services essential to the safety of personnel onboard of offshore unit and services essential to the protection of the environment.

2.5.7 The procedure is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary.

2.5.8 Details of risks, and the means by which they are mitigated, are to be included in the operating manual, *see* 2.2.2.

2.5.9 Risk Based Analysis (RBA) technique is to be selected from IEC/ISO 31010 *Risk Management – Risk Assessment Techniques*. The technique selected is to be carried out in accordance with the relevant International Standard or applicable National Standard and with 2.5.10 to 2.5.14. A justification is to be provided which demonstrates the suitability of the Standard and analysis technique chosen.

2.5.10 The RBA is to demonstrate that suitable risk mitigation has been achieved for all normal and foreseeable abnormal conditions. The scope of analysis required for each system is defined in 2.5.11 to 2.5.14 and in the respective parts of the Rules.

2.5.11 The RBA is to be organised in terms of items of equipment and function. The effects of item failures or damage at stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

2.5.12 RBA is to:
(a) Identify the equipment or sub-system and their mode of operation;
(b) Identify potential failure modes and damage situations and their causes;
(c) Evaluate the effects on the system of each failure mode and damage situation;
(d) Identify measures for reducing the risks associated with each failure mode;
(e) Identify measures for failure mitigation; and
(f) Identify trials and testing necessary to prove conclusions.

2.5.13 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g., failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, failure need only be dealt with as a cause of failure of the pump.

2.5.14 Where RBA is used for consideration of systems that depend on software based functions for control or co-ordination, the analysis is to investigate failure of the function rather than a specific analysis of the software code.

2.6 Configuration management

2.6.1 A configuration management procedure is to be established in order to ensure traceability of the configuration of the integrated software intensive system, its subsystems and its components.

2.6.2 The procedure is to identify items essential for the safety or operation of the integrated software intensive system (configuration control items) which could foreseeably be changed during the lifetime of the integrated software intensive system, including:
(a) Documentation.
(b) Software.
(c) Sensors.
(d) Actuators.
(e) Instrumentation.
(f) Valves.
(g) Pumps.
(h) BOP stacks.

2.6.3 The procedure is to take account of the design requirements, *see* 2.8.

2.6.4 The procedure is to include items used to mitigate risks, *see* 2.5.

2.6.5 The procedure is to ensure that any changes to configuration control items are:
(a) Identified.
(b) Recorded.
(c) Evaluated.
(d) Approved.
(e) Incorporated.
(f) Verified.

2.6.6 The procedure is to specify the required software testing for any changes to configuration control items for the whole lifecycle of the integrated software intensive system.

2.7 Requirements definition

2.7.1 A requirements definition procedure is to be established in order to define the functional behaviour and performance throughout the whole lifecycle of the integrated software intensive system required by individual stakeholders, in the environments to which the integrated software intensive system is likely to be exposed under both normal and foreseeable emergency conditions.

2.7.2 The procedure is to take account of requirements resulting from key stakeholders, including:
(a) Owner.
(b) Operator.
(c) Crew.
(d) Shipyard.
(e) Systems integrator.
(f) Maintenance personnel.
(g) Surveyors.
(h) Manufacturers and suppliers.
(j) National Administration.
(k) LR.

2.7.3 The procedure is to take account of requirements resulting from the following influences:
(a) Offshore unit operations, *see* 2.5.5(a).
(b) Ship conditions, *see* 2.5.5(b).
(c) Environmental conditions, *see* 2.5.5(d).
(d) Applicable provisions, including:
Statutory legislation;
classification requirements;
international standards;
national standards; and
codes of practice.
(e) Expected users, including:
Multi-national users with a range of national languages and cultures
fatigued users;
users without dedicated training; and
maintenance and survey personnel.
(f) Design, construction and operational constraints, including:
Effect of particular design decisions or component choices on other aspects of design, risk and production engineering compromises, verification, integration and validation considerations, maintenance and disposal, and changes in use.

2.7.4 The procedure is to specify the functional behaviour and performance requirements and is to identify the source of the requirements.

2.7.5 The requirements specification is to fully specify, either directly or by reference to other submitted documents, all external interfaces between the software product and other software or hardware.

2.7.6 The procedure is to detail required functions the integrated software intensive system is to perform under both normal and foreseeable abnormal conditions.

2.7.7 The procedure is to define specific boundary conditions of each required function of the integrated software intensive system.

2.7.8 The procedure is to ensure overall integrity of the system requirements through verification and analysis of integrity of sets of requirements.

2.8 Design definition

2.8.1 A design definition procedure is to be established in order to define the requirements for the design of the integrated software intensive system which satisfies stakeholder requirements, quality assurance requirements, risk mitigate requirements and complies with basic internationally recognised design requirements for safety and functionality.

2.8.2 The procedure is to ensure that the design of the integrated software intensive system satisfies:
(a) Statutory legislation.
(b) LR's requirements.
(c) International Standards and Codes of Practice where relevant.

2.8.3 The procedure is to take account of stakeholder requirements, *see* 2.7.

2.8.4 The procedure is to take account of quality assurance requirements, *see* 2.4.

2.8.5 The procedure is to take account of risk management requirements, *see* 2.5.

2.8.6 The procedure is to ensure that the requirements for the design of major components and subsystems of the integrated software intensive system can be verified before and after integration.

2.8.7 The procedure is to specify the design requirements and is to identify the source of the requirements.

2.8.8 Any deviations from stakeholder requirements are to be identified, justified and accepted by the originating stakeholder, communicated to involved stakeholders and documented.

2.9 Implementation

2.9.1 An implementation procedure and technology is to be selected in order to realise specific integrated software intensive system that satisfies the design requirements of the machinery or an engineering system or integrated software intensive system through verification, *see* 2.11 and satisfies stakeholder requirements through validation, *see* 2.12.

2.9.2 The procedure and technology is to take account of quality assurance requirements, *see* 2.4.

2.9.3 The procedure and technology is to take account of design requirements, *see* 2.8.

2.9.4 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 6, Ch 1,2.13.2 and 2.13.7 of the Rules for Ships. Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the manufacturer.

2.9.5 To demonstrate compliance with 2.9.4:
(a) software quality plans and safety evidence are to be submitted for consideration;
(b) an assessment inspection of the manufacturer's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR; and
(c) for software development lifecycle, an evidence of satisfying internationally recognised standards and practices that are acceptable to LR is to submit for consideration of satisfying 2.9.4(b).

2.10 Integration

2.10.1 An integration procedure is to be established in order to ensure that the integrated software intensive system is assembled in a sequence which allows verification of individual system, individual subsystems and major components following integration in advance of validating the entire integrated software intensive system.

2.10.2 The procedure is to take account of the verification requirements, *see* 2.11.

2.10.3 The procedure is to identify the subsystems and major components, the sequence in which they are to be integrated, the points in the project at which integration is to be carried out, and the points in the project at which verification is to be carried out.

2.11 Verification

2.11.1 A verification procedure is to be established in order to ensure that systems, subsystems and major components of the integrated software intensive system satisfy their design requirements.

2.11.2 The procedure is to verify design requirements, *see* 2.8.

2.11.3 The procedure is to identify the requirements to be verified, the means by which they are to be verified, the verification methods and techniques, and the points in the project at which verification is to be carried out.

2.11.4 The procedure is to be based on one or a combination of the following activities as appropriate:
(a) Design review.
(b) Product inspection.
(c) Process audit.
(d) Product testing.

2.12 Validation

2.12.1 A validation procedure is to be established in order to ensure the functional behaviour and performance of the integrated software intensive system meets with its functional and performance requirements in its intended operational environment.

2.12.2 The procedure is to validate stakeholder requirements, *see* 2.7.

2.12.3 The procedure is to validate arrangements required to mitigate risks, *see* 2.5.

2.12.4 The procedure is to validate the traceability of the configuration control items, *see* 2.6.

2.12.5 The procedure is to identify the requirements to be validated, the means by which they are be validated and the points in the project at which validation is to be carried out, including:
(a) Factory acceptance testing.
(b) Integration testing.
(c) Commissioning.
(d) Sea trials.
(e) Survey.

■ *Section 3* **Software**

3.1 General, scope and objectives

3.1.1 Where software is used as the implementation technology for the ISIS then the additional requirements in 3.1.2 to 3.1.9 are to be applied. Where a proposed activity is not undertaken, justification is to be documented and submitted.

3.1.2 A plan for the production of software is to be produced and is to include, but not limit to, the elements listed below.
(a) A full list of software components being developed and, for each, what is required to be produced including code artefacts, tools, specifications, design models, and documentation.
(b) The identification of the deliverables, including those for the purposes of late project phase activities such as boat/platform integration, boat trials, operations and maintenance.
(c) Details of any work that is being subcontracted and how the subcontract will be managed, including specifically ensuring that the Software Development Plan for the software lifecycle will be adhered to.
(d) An identification of the principal project risks arising from the development work.
(e) A definition of the software lifecycle is to be deployed.
(f) The processes, methods, techniques and tools to be used for each phase of the software lifecycle, including:
- pedigree of chosen language, tools and design methods;
- the identification of specific software architecture and software design features appropriate to the reliance being placed on the software; and
- verification performed at each stage of the lifecycle including measures to show that all the requirements, have been correctly translated or implemented by the lifecycle phase activities.

(g) Identify the key personnel in the software development team and in any subcontractors, and their responsibilities. The competency of software development team, especially experience of using the processes, methods, techniques and tools to be used.
(h) Analysis of the software architecture and the software design to confirm that the specific design features which are implemented by functions to satisfy the requirements will work as intended in all modes of operation and failure conditions.

(j) Details of the code implementation and coding standards to be applied to ensure that the software code will be reliable and maintainable.

(k) Validation activities to demonstrate that the functions of the software specifically implemented to satisfy the requirements will operate as intended in all feasible operating scenarios, including:
- testing to show that hazard mitigations work as intended;
- testing and demonstration of safe and acceptable behaviour even in unexpected states, modes and failure conditions; and
- testing that functions implemented to satisfy the requirements work in all credible operating scenarios.

3.1.3 Additional requirements for verification and validation of software components in software-based control systems that handles safety and critical operational functions are listed in 3.1.4 to 3.1.9.

3.1.4 Evidence of satisfying the requirements of ISO/IEC 21119: *Software and Systems Engineering – Software Testing*, or ISO/IEC 61508-3 *Functional safety of electrical/electronic/programmable*, is to meet requirements 3.1.5 to 3.1.9 in this sub-Section.

3.1.5 Evidence is to be submitted that software test scenarios and software test results cover all of the independent paths. Evidence is to be submitted that test results and software static tests on control flow, data flow and design review are to be used to analyse the quality of software code.

3.1.6 For the purpose of black-box testing, evidence is to be submitted that test results, methods, techniques and tools that are acceptable to LR are applied before and after integrations.

3.1.7 Evidence is to be submitted that test results and software tests listed below are to be applied for software verification:

(a) Dynamic analysis and testing for:
    Boundary values, structural test coverage (entry points) 100 per cent and structural test coverage (statements) 100 per cent.

(b) Static analysis and testing for:
    Control flow, data flow and design review.

(c) Functional and black box testing on:
    Equivalence classes and input partition testing including boundary value analysis.

(d) Performance testing for:
    Response timings and memory constraints, performance requirements.

(e) Data recording and analysis.

(f) Regression testing.

3.1.8 Evidence is to be submitted that test results and software tests listed below are to be applied for software validation:
- Functional and black box testing.

3.1.9 Evidence that coding reviews have been undertaken is to be submitted.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines and cover the unit types indicated in 1.2.

1.1.2 The requirements of this Chapter also apply to liftboats whose primary function is to provide support services to offshore wind turbine installations or other types of offshore installation, *see* 1.2.

1.1.3 The requirements in this Chapter are supplementary to those given in the relevant Parts of the Rules.

1.1.4 Surface type units and surface type self-elevating units are to comply with LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), but aspects which relate to the specialised offshore function of the unit will also be considered on the basis of these Rules.

1.1.5 Requirements additional to these Rules may be imposed by the National Authority with whom the unit is registered and/or by the Administration within whose territorial jurisdiction the unit is operating.

1.2 General definitions

1.2.1 A **column-stabilised unit** is a unit with a working platform supported on widely spaced buoyant columns. The columns are normally attached to buoyant lower hulls or pontoons. These units are normally floating types but can be designed to rest on the sea bed.

1.2.2 A **liftboat** is a unit with a buoyant hull (generally either triangular or pontoon shaped) with moveable legs capable of raising the hull above the surface of the sea and designed to operate as a sea bed-stabilised unit in an elevated mode. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. In general, installation and maintenance activities would be undertaken in the jacked-up condition. These unit types are generally self-propelled.

1.2.3 A **self-elevating (or jack-up) unit** is a floating unit which is designed to operate as a sea bed-stabilised unit in an elevated mode. These units have a buoyant hull (generally either triangular or pontoon shaped) with movable legs capable of raising its hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. These unit types are generally not fitted with a propulsion system.

1.2.4 A **surface type floating unit** is a unit with a ship or barge type displacement hull of single or multiple hull construction intended for operation in the floating condition.

1.2.5 A **surface type self-elevating (or jack-up) unit** is a floating unit, which is designed to operate as a sea bed-stabilised unit in an elevated mode. These units have a ship type displacement hull of single or multiple hull construction fitted with moveable legs capable of raising the hull above the surface of the sea. The legs may be designed to penetrate the sea bed, or be attached to a mat or individual footings which rest on the sea bed. In general, installation and maintenance activities would be undertaken in the jacked-up condition. These unit types are generally self-propelled.

1.2.6 Further general definitions for all unit types can be found in Pt 1, Ch 2,2.

1.3 Guidance note

1.3.1 Summary information for unit types engaged in installation and/or maintenance activities relating to offshore wind turbines can be found in LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*.

1.3.2 Summary information for Liftboats engaged in support services to offshore wind turbine installation or other types of offshore installation can be found in LR's Guidance Note *Mobile Offshore Units – Liftboats*.

1.3.3 The Guidance Notes referred to in 1.3.1 and 1.3.2 provide summary information on the following topics:

- Classification Rules, Regulations and procedures.
- National Administration requirements.
- Documentation.
- Applicable LR Rule requirements for unit types identified in 1.2.

1.3.4 For the unit types identified in 1.2.1, 1.2.3, 1.2.4 and 1.2.5, Appendices A2, A3, A4 and A5 of the Guidance Note referred to in 1.3.1 include summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types.

1.3.5 For the unit type identified in 1.2.2, the Guidance Note referred to in 1.3.2 includes summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types.

1.4 Class notations

1.4.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.4.2 In general, units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines, which comply with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of the following class type notations:

- **MainWIND**

1.4.3 In general, liftboats whose primary function is to provide support services to offshore wind turbine installations or other types of offshore installation which comply with the requirements of this Chapter and the relevant Parts of the Rules will be eligible for the assignment of the following class type notations:

- **Liftboat**

1.4.4 Units engaged in more than one function may be assigned a combination of class type notations at the discretion of the Classification Committee.

1.4.5 Lifting appliances are to comply with LR's *Code for Lifting Appliances in a Marine Environment* (LAME), *see also* Chapter 11.

1.4.6 Where the lifting appliances form an essential feature of a classed unit, the special feature class notation '**LA**' will be assigned, *see* Chapter 11.

1.4.7 Other special features class notations associated with lifting appliances may be assigned, *see* Chapter 11.

1.4.8 Where the lifting appliance is not assigned a special feature class notation, the crane is to be certified by a recognised competent body, *see* Ch 1, 1.2 of LR's LAME.

1.5 Scope

1.5.1 The following additional topics applicable to the class type notation are covered by this Chapter:

- Hull scantlings
- Strength of structure for accommodation.
- Supports for containerised modules.
- Structure in way of cranes.
- Structure below any other major mission equipment, laydown areas, etc.
- Positional mooring.
- Main and auxiliary machinery.
- Control and electrical engineering.
- Safety systems, hazardous areas and fire.
- Corrosion control.

1.6 Installation layout and safety

1.6.1 Living quarters, lifeboats and other evacuation equipment are to be located in non-hazardous areas.

1.6.2 The requirements for fire safety are to be in accordance with the requirements of a National Administration, *see* Pt 1, Ch 2,1 and Pt 7, Ch 3.

1.6.3 Additional requirements for hazardous areas, safety and communication systems are given in Part 7 and are to be applied to the relevant unit type. For surface type self-elevating units, the requirements for surface type units are to be complied with as applicable.

1.7 Survey

1.7.1 For all unit types, the requirements for periodical surveys are defined in Pt 1, Ch 2,3 and Ch 3.

1.7.2 In general, where a classed or certified lifting appliance is fitted to a classed unit, the survey requirements of the lifting appliance are to be in accordance with Chapter 12 of LR's LAME and Part E, Ch 8 of LR's *Marine Survey Procedures Manual*.

1.8 Plans and data submission

1.8.1 Plans, calculations and data are to be submitted as required by the relevant Parts of the Rules, together with the additional plans and information listed in this Chapter.

1.8.2 For units or vessels engaged in installation and/or maintenance activities relating to offshore wind turbines, *see also* Ch 2,8 of LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*, for additional information on the plans and data to be submitted.

1.8.3 For liftboats engaged in support services to offshore wind turbine installation, *see also* LR's Guidance Note *Mobile Offshore Units – Liftboats*, for additional information on the plans and data to be submitted.

Section 2
Structure

2.1 Plans and data submission

2.1.1 In addition to the structural plans and information as required by Ch 2,8 of LR's Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels* and also LR's Guidance Note *Mobile Offshore Units – Liftboats*, the following additional plans and information are to be submitted as applicable:

- General arrangement plans.
- Structural plans of the accommodation including deck houses and modules.
- Design calculations for containerised modules (if applicable).
- Structural arrangements in way of crane supports and boom rests (if applicable).
- Structural arrangements in way of permanently attached, purpose built cargo stacking and securing arrangements.
- Structural arrangements under the weather deck which support heavy items of deck cargo such as nacelles, towers, blades, foundations and temporary transportation frames.
- Structural arrangements and supports under any other major mission or topsides equipment.
- Positional mooring equipment and supporting structures (if applicable).

2.2 General

2.2.1 The hull strength is to take into account the applied weights and forces due to the accommodation, deck cargo, cranes and, if applicable, mooring forces and the local structure is to be suitably reinforced. Appendices A2, A3, A4 and A5 of the Guidance Note referred to in 1.3.1 include summary Tables indicating the relevant Parts and Chapters of these Rules and the Rules for Ships, which are to be applied to the individual unit types for hull strength requirements.

2.2.2 For the unit types identified in 1.2.1, 1.2.3, 1.2.4 and 1.2.5, the hull scantlings for each unit type are to be calculated in accordance with the relevant parts of the Rules identified in Appendices A2, A3, A4 and A5 of the Guidance Note *Mobile Offshore Units – Wind Turbine Installation Vessels*.

2.2.3 For the unit type identified in 1.2.2, the hull scantlings for each unit type are to be calculated in accordance with the relevant parts of the Rules identified in the Guidance Note *Mobile Offshore Units – Liftboats*.

2.2.4 The design loadings for all purpose built cargo stacking arrangements, support frames and trusses are to be defined by the designers/Builders and calculations are to be submitted in accordance with an internationally recognised Code or Standard as defined in Appendix A. The supporting structure and attachments below the purpose built cargo stacking arrangements, support frames and trusses are to be designed for all operating conditions and for the emergency condition as defined in Ch 8,1.4. For a surface type self-elevating unit in the afloat condition, the angle of inclination in the emergency static condition is to be considered in accordance with the requirements for a self-elevating unit.

2.2.5 The supporting structure and attachments below any other mission equipment items are to be designed for all operating conditions and for the emergency condition as defined in Ch 8,1.4. For a surface type self-elevating unit in the afloat condition, the angle of inclination in the emergency static condition is to be considered in accordance with the requirements for a self-elevating unit.

2.2.6 When the unit is intended to operate in an area which could result in the build-up of ice on the crane, leg and any other structure, the effects of ice loading are to be included in the calculations. *See* Pt 4, Ch 3,4.

2.2.7 For column-stabilised and self-elevating units, the decks and other under-deck structure supporting the mission equipment and deck cargo are to be suitable for the local loads at the mission equipment and deck cargo support points and an agreed uniformly distributed load acting on the deck. *See* Pt 4, Ch 6,2.

2.2.8 For surface type and surface type self-elevating units, the decks and other under-deck structure supporting the mission equipment and deck cargo are to be suitable for the local loads at the mission equipment and deck cargo support points and an agreed uniformly distributed load acting on the deck. *See* Pt 3, Ch 3,5 of the Rules for Ships.

2.2.9 In general, all seatings, platform decks, girders and pillars supporting mission equipment and deck cargo are to be arranged to align with the main hull structure, which is to be suitably reinforced, where necessary, to carry the appropriate loads.

2.2.10 Attention should be paid to the capability of support structures to withstand buckling. For column-stabilised and self-elevating units, *see* Pt 4, Ch 5,4. Surface type and surface type self-elevating units are to comply with Pt 3, Ch 4,7 of the Rules for Ships, but aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 4, Ch 5,4.

2.2.11 Crane pedestals are classification items and are to comply with the requirements of Chapter 11.

2.2.12 For liftboats, a fatigue life assessment of all relevant structural elements in accordance with Pt 4, Ch 5,5 is required. Structural elements to be assessed include lattice legs and connections to mats and footings and leg support structure. The fatigue loading spectrum may be based on the transit environmental criteria.

2.2.13 The minimum fatigue life of a liftboat is to be specified by the Owners, but is generally not to be less than 20 years, unless agreed otherwise with LR.

2.2.14 For liftboats, when considering the overturning moment, in no case is the variable load to be taken greater than 10 per cent of the maximum variable load. The percentage of variable load used when considering the overturning moment is to be stated in the Operations Manual.

2.2.15 For liftboats, when calculating the overturning moment, the unit should be considered supported through the centre line of the legs about which the unit is considered rotating. However, for hard foundation bases, the maximum stressed edge of the mat may be taken as an appropriate support position. In this instance, a safety factor of at least 1,2 against overturning is considered acceptable.

2.2.16 For liftboats, the Owner is to specify the minimum design environmental criteria and return periods for which the unit is to be approved. In general, a return period of not less than 1 year should be used for operational conditions and 100 years for survival conditions.

2.2.17 For liftboats, restricted to seasonal operations in order to avoid extremes of wind and wave, such seasonal limitations must be specified. The unit's actual minimum design environmental criteria and return periods used in the design of the liftboat are to be stated in the Operations Manual.

2.2.18 The thickness of marine growth to be taken into account during the design of submerged members on lift boats is not to be less than 50 mm. The actual thickness of marine growth used in the design of the liftboat is to be stated in the Operations Manual and the design limit is not to be exceeded in service.

2.2.19 For liftboats, the minimum design deck loads are to be specified by the Owner and are not to be less than the minimum design deck loads required by Pt 4, Ch 6,2.

2.2.20 For liftboats, the foundation fixity need not be considered for the in-place strength analysis.

2.3 Deckhouses and modules

2.3.1 For column-stabilised and self-elevating units, the scantlings of structural deckhouses are to comply with Pt 4, Ch 6,9. Where deck-houses support equipment loads, they are to be suitably reinforced.

2.3.2 For surface type and surface type self-elevating units, the scantlings of structural deckhouses are to comply with Pt 3, Ch 8,2 of the Rules for Ships. Where deck-houses support equipment loads, they are to be suitably reinforced.

2.3.3 The strength of containerised modules which do not form part of the main hull structure will be specially considered in association with the design loadings.

2.3.4 When containerised modules can be subjected to wave loading or protect openings leading into buoyant spaces, the scantlings are not to be less than required by 2.3.1 or 2.3.2, as applicable.

2.3.5 For column-stabilised and self-elevating units, the structural strength of the connections between containerised modules and the supporting frame or structure are to comply with the general strength requirements of Pt 4, Ch 6,9, taking into account the unit's motions and marine environmental aspects. For surface type and surface type self-elevating units, the scantlings of structural deckhouses are to comply with Pt 3, Ch 8,2 of the Rules for Ships.

2.3.6 The connections of containerised modules are also to satisfy an emergency static condition with an applied horizontal force F_H in any direction as follows:

$$F_H = W \sin\theta \text{ N (tonne-f)}$$

where

θ = 25° for semi-submersible and surface type units

θ = 17° for self-elevating and surface type self-elevating units

W = weight of the modules supported in N (tonne-f).

2.3.7 In the emergency static condition, defined in 2.3.6, the permissible stress levels are to be in accordance with Pt 4, Ch 5, 2.1.1(c).

2.4 Permissible stresses

2.4.1 In general, for column-stabilised and self-elevating units the permissible stresses in the structure in operating, transit and survival conditions are to comply with Pt 4, Ch 5,2, but the minimum scantlings of the local structure are to comply with Pt 4, Ch 6.

2.4.2 In general, for surface type and surface type self-elevating units the primary hull strength and the minimum scantling requirements for the local structure can be considered under Pt 3, Ch 4 and Pt 4, Ch 1 of the Rules for Ships. However, aspects which relate to the specialised offshore function of the unit will be considered under the basis of Pt 4, Ch 5,2.

2.4.3 Permissible stresses for lattice type structures may be determined from an acceptable code, *see* Appendix A.

2.5 Watertight and weathertight integrity

2.5.1 For column-stabilised and self-elevating units, the general requirements for watertight and weathertight integrity are to be in accordance with Pt 4, Ch 7.

2.5.2 For surface type and surface type self-elevating units, the general requirements for watertight and weathertight integrity are to be in accordance with Pt 3, Ch 11 and Ch 12 of the Rules for Ships.

2.5.3 The integrity of the weather deck is to be maintained. Where mission equipment penetrates the weather deck and is intended to constitute the structural barrier to prevent the ingress of water to spaces below the deck, its structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in superstructures or deck-houses fully complying with the Rules. Full details are to be submitted for approval.

2.5.4 Where items of mission equipment penetrate watertight boundaries, the watertight integrity is to be maintained and full details are to be submitted for approval.

2.6 Materials

2.6.1 For column-stabilised and self-elevating units, the general requirements for materials are to be in accordance with Pt 3, Ch 1,4 and Pt 4, Ch 2.

2.6.2 For surface type and surface type self-elevating units, the general requirements for materials are to be in accordance with Pt 3, Ch 2 and Pt 4, Ch 1,2 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered under the basis of Pt 3, Ch 1,4 and Pt 4, Ch 2.

■ *Section 3*
Positional mooring systems

3.1 Application

3.1.1 The requirements of this Section apply to units which are intended to perform their primary designed service function only while they are moored with a catenary type positional mooring system including thruster-assisted systems.

3.1.2 The mooring system will be considered for classification on the basis of operating constraints and procedures specified by the Owner and recorded in the Operations Manual.

3.1.3 The mooring system is to comply with the requirements of Chapter 10.

3.1.4 For column-stabilised and self-elevating units, dynamic positioning systems are to comply with the requirements of Chapter 9. For surface type and surface type self-elevating units, dynamic positioning systems are to comply with the requirements of Pt 7, Ch 4 of the Rules for Ships.

3.1.5 The support structure in way of fairleads and winches, etc., are to be in accordance with Pt 4, Ch 6,1.

■ *Section 4*
Main and auxiliary machinery

4.1 Application

4.1.1 For surface type units, the general requirements for main and auxiliary machinery are to be in accordance with Pt 5, Ch 1 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 5, Ch 1 and are to be complied with as applicable. All other main and auxiliary machinery requirements are to be in accordance with Pt 5, Ch 2 to Ch 22 of the Rules for Ships and are to be complied with as applicable.

4.1.2 For surface type self-elevating units, the general requirements for main and auxiliary machinery are to be in accordance with Pt 5, Ch 1 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 5, Ch 1 and Ch 4,2, and are to be complied with as applicable. All other main and auxiliary machinery requirements are to be in accordance with Pt 5, Ch 2 to Ch 22 of the Rules for Ships and are to be complied with as applicable.

4.1.3 For both column-stabilised and self-elevating units, the main and auxiliary machinery requirements are to be in accordance with Part 5 and are to be complied with as applicable.

4.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

4.2 Angle of inclination

4.2.1 For surface type units, the angles of inclination are to be in accordance with Table 1.3.2 in Pt 5, Ch 1,3.7 of the Rules for Ships.

4.2.2 For surface type self-elevating units in the afloat conditions, the angles of inclination are to be in accordance with Table 1.3.2 in Pt 5, Ch 1,3.7 of the Rules for Ships.

4.2.3 For both column-stabilised and self-elevating units, the angles of inclination are to be in accordance with Tables 1.3.3 and 1.3.4, respectively, in Pt 5, Ch 1,3.7.

4.3 Bilge systems and cross flooding arrangements

4.3.1 For all unit types with accommodation for more than 12 persons who are not crew members, the requirements of Pt 3, Ch 4,3 are to be complied with as applicable.

4.4 Jacking gear machinery

4.4.1 For all types of self-elevating units, the number of jacking cycles expected to be seen during the unit's intended design life will need to be specially considered in the design of the jacking gear machinery. Relevant calculations will be required to be submitted, taking into account the expected number of jacking cycles during the unit's intended design life.

■ *Section 5* Control and electrical engineering

5.1 Application

5.1.1 For surface type units, the control and electrical engineering requirements are to be in accordance with Part 6 of the Rules for Ships, and are to be complied with as applicable.

5.1.2 For surface type self-elevating units, the control and electrical engineering requirements are to be in accordance with Part 6 of the Rules for Ships. Aspects which relate to the specialised offshore function of the unit will be considered on the basis of Pt 6, Ch 1 and Ch 2 and are to be complied with as applicable.

5.1.3 For both column-stabilised and self-elevating units, the main and auxiliary machinery requirements are to be in accordance with Part 6 and are to be complied with as applicable.

5.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

5.2 Angle of inclination

5.2.1 For surface type units, the angles of inclination are to be in accordance with Table 2.1.1 in Pt 6, Ch 2,1.9, of the Rules for Ships.

5.2.2 For surface type self-elevating units in the afloat conditions, the angles of inclination are to be in accordance with Table 2.1.1 in Pt 6, Ch 2,1.9 of the Rules for Ships.

5.2.3 For both column-stabilised and self-elevating units, the angles of inclination are to be in accordance with Table 2.1.1 in Pt 6, Ch 2,1.9.

5.3 Emergency source of electrical power

5.2.1 For all unit types with accommodation for more than 50 persons who are not crew members, the requirements of Pt 3, Ch 4,4.2 are to be complied with as applicable.

■ *Section 6* Safety systems, hazardous areas and fire

6.1 Application

6.1.1 For all unit types, the safety systems, hazardous areas and fire safety requirements are to be in accordance with the requirements of Part 7, and are to be complied with as applicable.

6.1.2 The requirements of Pt 7, Ch 1,9.1, are not applicable to surface type units and surface type self-elevating units. For these unit types, the requirements of Pt 3, Ch 11,9 of the Rules for Ships are to be complied with as applicable.

6.1.3 For surface type self-elevating units, the remaining requirements in Part 7 for surface type units are to be complied with as applicable.

6.1.4 For all unit types, due account should be taken of the unit type and operational role when applying these requirements.

■ *Section 7* Corrosion control

7.1 Application

7.1.1 For all unit types, the corrosion control requirements are to be in accordance with Part 8 and are to be complied with as applicable.

7.1.2 The minimum corrosion protection requirements for external structural steel work for surface type self-elevating units are to comply with Table 1.1.1 in Pt 8, Ch 1. The unit's main hull and all structure above the splash zone are to comply with the requirements for a surface type unit. The legs, footings and mats for these units are to comply with the requirements for a self-elevating unit.

Section A1 Codes and Standards

A1.1 Abbreviations

A1.1.1 The following abbreviations are used in this Appendix:

AISC	American Institute of Steel Construction.
ANSI	American National Standards Institute.
API	American Petroleum Institute.
ASME	American Society of Mechanical Engineers.
BS	British Standard.
CSA	Canadian Standards Association.
DIN	Deutsches Institut für Normung.
FEM	Fédération Européenne de la Manutention.
IP	International Petroleum.
ISO	International Standards Organisation.
NACE	National Association of Corrosion Engineers.
NS	Norwegian Standard.
NFPA	National Fire Protection Association.
TBK	Norwegian Pressure Vessel Committee.
UKOOA	United Kingdom Offshore Operators Association.

A1.2 Recognised Codes and Standards

A1.2.1 The following Codes and Standards are recognised by LR in connection with the design, construction and installation of machinery, equipment and systems which form part of the drilling plant facility, production and process plant facility and riser systems installed on offshore units as appropriate. Codes are also given for structural components, concrete structures, bearings and formulations used in positional mooring systems.

A1.2.2 The following National and International Codes and Standards listed are subject to change/deletion without notice. The latest edition of a Code or Standard, with all applicable addenda, current at the date of contract award should be used.

A1.2.3 When requested, other National and International Codes and Standards may be used after special consideration and agreement by LR.

A1.2.4 **Blow out prevention**:

API Spec. 16A	*Specification for Drill through Equipment.*
API Std 53	*Blowout Prevention Equipment Systems for Drilling Operations.*
API RP 16E	*Design of Control Systems for Drilling Well Control Equipment.*

A1.2.5 **Lifting appliances for blow out preventer and burner boom, and other equipment**:

API Spec 2C	*Specification for Offshore Pedestal Mounted Cranes.*
ASME B30.20	*Below the Hook Lifting Devices.*
API Spec 8C	*Drilling and Production Hoisting Equipment.*
FEM 1.001	*Section-1: Heavy lifting appliances – Rules for the design of Hoisting Appliance Methods of Strength Calculation.*
ISO 2374	*Lifting Appliances – Range of Maximum Capacities for Basic Models.*
ISO 10245	*(all parts) Cranes – Limiting and indicating devices.*
ISO 13534	*Petroleum and natural gas industries – Drilling and production equipment – Inspection, maintenance, repair and remanufacture of hoisting equipment.*
ISO 13535	*Petroleum and natural gas industries – Drilling and production equipment – Hoisting equipment.*

LR's *Code for Lifting Appliances in a Marine Environment.*

A1.2.6 **Derrick**:

API 4E	*Drilling and Well Servicing Structures.*

A1.2.7 **Drilling equipment**:

API Spec. 7	*Specification for Rotary Drilling Equipment.*
API RP 7G	*Drill Stem Design and Operating Limits.*
API Spec. 8A and 8C	*Drilling and Production Hoisting Equipment.*
API RP 8B	*Hoisting Tool Inspection and Maintenance Procedures.*
API Spec. 9A	*Wire Rope.*
API RP 9B	*Application, Care and Use of Wire Rope for Oil Field Service.*
ISO 10405	*Petroleum and natural gas industries – Care and use of casing and tubing.*
ISO 10407	*Petroleum and natural gas industries – Drilling and production equipment – Drill stem design and operating limits.*
ISO 10426	*Petroleum and natural gas industries – Cements and materials for well cementing.*
ISO 11960	*Petroleum and natural gas industries – Steel pipes for use as casing or tubing for wells.*
ISO 11961	*Petroleum and natural gas industries – Steel pipes for use as drill pipe – Specification.*
ISO 13500	*Hydraulic fluid power – Determination of particulate contamination by automatic counting using the light extinction principle.*
ISO 13533	*Petroleum and natural gas industries – Drilling and production equipment – Drill-through equipment.*
ISO 14693	*Petroleum and natural gas industries – Drilling and well-servicing equipment.*

ISO 13678	*Petroleum and natural gas industries – Evaluation and testing of thread compounds for use with casing, tubing and line pipe.*
ISO 13680	*Petroleum and natural gas industries – Corrosion-resistant alloy seamless tubes for use as casing, tubing and coupling stock – Technical delivery conditions.*
FEM 1001 3rd Edition:	*Rules for the Design of Hoisting Appliances, Section 1, Booklets 3 to 8.*

A1.2.8 **Wellhead equipment**:

API Spec. 6A & ISO 10423	*Wellhead and Christmas Tree: Equipment*.
API Spec. 14D	*Wellhead Surface Safety Valves and Underwater Safety Valves for Offshore Service.*
API RP 14B	*Design, Installation and Operation of Subsurface Safety Valve Systems.*
API RP 17D	*Specification for Subsea Wellhead and Christmas Tree Equipment.*

A1.2.9 **Piping**:

ASME B16.47	*Large Diameter Steel Flanges: NPS 26 Through NPS 60.*
ASME B16.5	*Pipe Flanges and Flanged Fittings.*
ANSI/ASME B31.3	*Process piping.*
BS 3351	*Specification for Piping Systems for Petroleum Refineries and Petrochemical Plants.*
ISO 13703	*Petroleum and natural gas industries – Design and installation of piping systems on offshore production platforms.*
API RP 14E	*Design and Installation of Offshore Production Platform Piping Systems.*
API RP 17B	*Flexible Pipe.*
API RP 520	*Design and Installation of Pressure Relieving Systems in Refineries.*
API RP 521	*Guide for Pressure Relieving and Depressurising Systems.*
API RP 16C	*Specification for Choke and Kill Systems.*
ISO 10434	*Bolted bonnet steel gate valves for the petroleum, petrochemical and allied industries.*
ISO 13623	*Petroleum and natural gas industries – Pipeline transportation systems.*
ISO 13847	*Petroleum and natural gas industries – Pipeline transportation systems – Welding of pipelines.*
ISO 14313	*Petroleum and natural gas industries – Pipeline transportation systems – Pipeline valves.*
ISO 15649	*Petroleum and natural gas industries – Piping.*
ISO 15761	*Steel gate, globe and check valves for sizes DN 100 and smaller, for the petroleum and natural gas industries.*
UKOOA	*Specification and Recommended Practice for the Use of GRP Piping Offshore.*

A1.2.10 **Riser and flow lines**:

API RP 2RD	*Riser Design.*
API RP 16R	*Design Rating and Testing of Marine Drilling Riser Couplings.*
API RP 16Q	*Design and Operation of Marine Drilling Riser Systems.*
API Bul 2J	*Comparison of Marine Drilling Riser Analysis.*
API RP 17B	*Recommended Practice for Flexible Pipe.*
API Spec.17J	*Specification for Unbonded Flexible Pipe.*
BS PD 8010	*Code of Practice for Pipelines, Part 3, Pipelines Subsea: Design, Construction and Installation.*
ISO 3183	*Petroleum and natural gas industries – Steel pipe for pipeline transportation systems*.
ISO 10414	*Petroleum and natural gas industries – Field testing of drilling fluids.*
ISO 10426	*Petroleum and natural gas industries – Cements and materials for well cementing.*
ISO 10427	*Petroleum and natural gas industries – Equipment for well cementing.*
ISO 11960	*Petroleum and natural gas industries – Steel pipes for use as casing or tubing for wells.*
ISO 15156	*Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production.*
ISO 15463	*Petroleum and natural gas industries – Field inspection of new casing, tubing and plain-end drill pipe.*
ISO 16070	*Petroleum and natural gas industries – Downhole equipment – Lock mandrels and landing nipples.*
ISO 18165	*Petroleum and natural gas industries – Performance testing of cementing float equipment.*
ISO 15590	*Petroleum and natural gas industries – Induction bends, fittings and flanges for pipeline transportation systems.*

A1.2.11 **Pressure vessels/fired units/heat exchangers**:

TBK-1-2	*General Rules for Pressure Vessels.*
PD 5500	*Unfired Fusion Welded Pressure Vessel.*
ASME Section 1	*Power Boilers.*
ASME Section IV	*Heating Boilers.*
ASME BPVC Sec I	*Boiler And Pressure Vessel Code, Section I, Rules For The Construction Of Power Boilers.*
ASME BPVC Sec IX	*Boiler And Pressure Vessel Code, Section Ix, Welding And Brazing Qualifications.*
ASME BPVC Sec V	*Boiler And Pressure Vessel Code, Section V, Nondestructive Examination.*
ASME BPVC Sec VIII-1	*Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 1.*

ASME BPVC Sec VIII-2	*Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 2 – Alternative Rules.*
ASME BPVC Sec VIII-3	*Boiler And Pressure Vessel Code, Section Viii, Rules For The Construction Of Pressure Vessels, Division 3 – Alternative Rules For Construction Of High Pressure Vessels.*
BS 2790	*Shell Boiler of Welded Construction.*
TEMA	*Standards of the Tubular Exchangers Manufacturers Association.*
EEMUA	*PUB No 143 Recommendations for Tube End Welding: Tubular Heat Transfer Equipment (Part 1 – Ferrous Materials).*
API RP 530	*Calculation of Heater. Tube Thickness in Petroleum Refineries.*
API 660	*Shell and tube heat exchangers for general refinery service.*
API 661	*Air Cooled Heat Exchangers for General Refinery Service.*
API 662	*Plate Heat Exchanger for General Refinery Services.*
BS EN 12952	*Water-Tube Steam Generating Plant.*
ISO 13706	*Petroleum, petrochemical and natural gas industries – Air-cooled heat exchangers.*
ISO 15547	*Petroleum, petrochemical and natural gas industries – Plate-type heat exchangers.*
ISO 13705	*Petroleum, petrochemical and natural gas industries – Fired heaters for general refinery service.*
ISO 16812	*Petroleum, petrochemical and natural gas industries – Shell-and-tube heat exchangers.*

A1.2.12 **Process plant equipment**:

API 610	*Centrifugal Pumps for General Refinery Service.*
API 615	*Sound Control of Mechanical Equipment for Refinery Service.*
API 617	*Centrifugal Compressors for General Refinery Services.*
API RP 14C	*Recommended Practices for Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms.*
API RP 550	*Recommended Practice: Manual on Installation of Refinery Instruments and Control Systems, Parts 1 to 4.*
API Std 613	*Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services.*
API Std 614	*Lubrication, Shaft-Sealing, and Control-Oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services.*
API Std 618	*Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services.*
API Std 619	*Rotary Type Positive Displacement Compressors for Petroleum, Chemical, and Gas Industry Services.*
API Std 620	*Design and Construction of large, welded, low-pressure storage tanks.*
API Std 650	*Welded steel tanks for oil storage.*
API Std 670	*Machinery Protection Systems.*
API Std 671	*Special purpose Couplings for Petroleum, Chemical and Gas Industry Services.*
API Std 672	*Packaged, integrally geared, centrifugal air compressors for petroleum, chemical and gas industry services.*
API Std 673	*Centrifugal Fans for Petroleum, Chemical and Gas Industry Service.*
API Std 674	*Positive displacement pumps – Reciprocating.*
API Std 675	*Positive displacement pumps – Controlled volume.*
API Std 676	*Positive displacement pumps – Rotary.*
API Std 681	*Liquid Ring Vacuum Pumps and Compressors for Petroleum, Chemical, and Gas Industry Services.*
API Std 682	*Shaft Sealing Systems for Centrifugal and Rotary Pumps.*
API 616	*Combustion Gas Turbines for General Refinery Service.*
ASME B73.1	*Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process.*
ASME B73.2M	*Specification for Vertical In-Line Centrifugal Pumps for Chemical Process.*
ISO 2314	*1973 Gas Turbine Acceptance Tests.*
ISO 2858	*End-suction centrifugal pumps (rating 16 bar) – Designation, nominal duty point and dimensions.*
ISO 2954	*Mechanical vibration of rotating and reciprocating machinery – Requirements for instruments for measuring vibration severity.*
ISO 3046	*(all parts) Reciprocating internal combustion engines – Performance.*
ISO 3977	*(all parts) Gas turbines – Procurement. ISO 5199 Technical specs. for centrifugal pumps- Class II.*
ISO 9906	*Roto-dynamic pumps – Hydraulic performance acceptance tests – Grades 1 and 2.*
ISO 10431	*Petroleum and Natural Gas Industries – Pumping Units – Specification.*
ISO 10436	*Petroleum and Natural Gas Industries – General purpose steam turbines for refinery service.*
ISO 10440	*(all parts) Petroleum and Natural Gas Industries – Positive displacement-rotary type compressors.*
ISO 10441	*Petroleum, petrochemical and natural gas industries – Flexible couplings for mechanical power transmission – Special-purpose applications.*
ISO 13707	*Petroleum and natural gas industries – Reciprocating compressors.*
ISO 14691	*Petroleum and natural gas industries – Flexible couplings for mechanical power transmission – General purpose applications.*

ISO 10437	*Petroleum, petrochemical and natural gas industries – Steam turbines – Special-purpose applications.*
ISO 10438	*Petroleum, petrochemical and natural gas industries – Lubrication, shaft-sealing and control-oil systems and auxiliaries.*
ISO 10439	*Petroleum, chemical and gas service industries – Centrifugal compressors.*
ISO 13631	*Petroleum and natural gas industries – Packaged reciprocating gas compressors.*
ISO 13691	*Petroleum and natural gas industries – High-speed special-purpose gear units.*
ISO 14310	*Petroleum and natural gas industries – Downhole equipment – Packers and bridge plugs.*
ISO 15136	*Downhole equipment for petroleum and natural gas industries – Progressing cavity pump systems for artificial lift.*
NFPA No. 37	*1975 Stationary Combustion Engines and Gas Turbines.*
EEMUA	*PUB No 141 Guide to the use of Noise Procedure Specification.*

A1.2.13 **General structural items (skids, support frames and trusses, helidecks, etc.)**:

CAP 437	*Offshore Helicopter Landing Areas – Guidance on Standards.*
BS 5950	*Structural Use of Steelwork in Building.*
AISC	*Manual of Steel Construction – Allowable Stress Design.*
BS 2853	*The Design and Testing of Steel Overhead Runway Beams.*
BS EN 1993	*Eurocode 3: Design of Steel Structures.*
BS 6399-2	*Loads for Buildings, Code of Practice for Wind Loads.*
BS 8118	*Structural Use of Aluminium.*
API BUL 2U	*Design of Flat Plate Structures.*
AISC LRFD	*Manual of Steel Construction – Load and Resistance Factor Design.*
API RP 2A – WSD	*Recommended Practice for Planning, Design and Constructing Fixed Offshore Platforms Working Stress Design.*
BS 8100	*Lattice Towers and Masts.*
API RP 2SK	*Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures.*
EN 1337-1:2000	*Structural bearings – Part 1: General design rules.*
EN 1337-2:2004	*Structural bearings – Part 2: Sliding elements.*
EN 1337-3:2005	*Structural bearings – Part 3: Elastomeric bearings.*
EN 1337-8	*Structural bearings – Part 8: Guide bearings and restrain bearings.*
EN 1337	*Structural bearings – Part 5: European Standard, Construction Standardisation: Pot Bearing.*
EN 1337-9:1997	*Structural bearings – Part 9: Protection.*
EN 1337-10	*Structural bearings – Part 10: Inspection and maintenance.*
EN 1337-11	*Structural bearings – Part 11: Transport, storage and installation.*
Euro-code 3	*Design of steel structures – Part 2: Steel Bridge.*
BS 5400 1984	*Steel, Concrete and Composite Bridges – Part 9: Bridge Bearing.*

A1.2.14 **Hazard area classification**:

API RP 500	*Classification of Locations for Electrical Installations at Petroleum Facilities.*
API RP 505	*Classification of Locations for Electrical Installations at Petroleum Facilities, Classed as Class I, Zones 0, 1 & 2.*
IP Code, Part 3	*Refining Safety Code.*
IP Code, Part 8	*Drilling and Production Safety Code for Offshore Operations.*
IP Code, Part 15	*Area Classification Code for Petroleum Installations.*
ISO 15138	*Petroleum and natural gas industries – Offshore production installations – Heating, ventilation and air-conditioning.*
ISO 17776	*Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment.*

A1.2.15 **Fire and safety standards:**

ISO 13702	*Petroleum and natural gas industries – Control and mitigation of fires and explosions on offshore production installations – Requirements and guidelines.*
ISO 15544	*Petroleum and natural gas industries – Offshore production installations – Requirements and guidelines for emergency response.*
NFPA No. 1	*Fire Prevention Code.*
NFPA No. 10	*Portable Extinguishers.*
NFPA No. 11	*Low-Expansion Foam.*
NFPA No. 11A	*Medium- and High-Expansion Foam Systems.*
NFPA No. 11C	*Mobile Foam Apparatus.*
NFPA No. 12	*Carbon Dioxide Systems.*
NFPA No. 12A	*Halon 1301 Systems.*
NFPA No. 13	*Sprinkler Systems.*
NFPA No. 14	*Standpipe, Hose Systems.*
NFPA No. 15	*Water Spray Fixed Systems.*
NFPA No. 16	*Deluge Foam-Water Systems.*
NFPA No. 16A	*Closed Head Foam-Water Sprinkler Systems.*
NFPA No. 17	*Dry Chem. Ext. Systems.*
NFPA No. 17A	*Wet Chem. Ext. Systems.*
NFPA No. 20	*Centrifugal Fire Pumps.*
NFPA No. 25	*Water-based Fire Protection Systems.*
NFPA No. 68	*Venting of Deflagrations.*
NFPA No. 69	*Explosion Prevention Systems.*
NFPA No. 80	*Fire Doors and Fire Windows.*
NFPA No. 170	*Fire Safety Symbols.*
NFPA No. 704	*Fire Hazards of Materials.*
NFPA No. 750	*Standard for Installation of Water Mist Fire Suppression System.*
NFPA No. 2001	*Clean Agent Ext. Systems.*
HSE OTI 95-634	*Jet Fire Resistance Test of Passive Fire Materials.*

A1.2.16 **Bearings**:

ANSI/AFBMA — *Std 11 – 1978 – Load Ratings and Fatigue Life for Roller Bearings.*

ASME 77-DE-39 — *Design Criteria to Prevent Core Crushing Failure in Large Diameter Case Hardened Ball and Roller Bearings.*

BS 5512:1991/ ISO 281:1990 — *Dynamic Load Ratings and Rating Life of Rolling Bearings.*

BS 5645:1987/ ISO 76:1987 — *Static Load Ratings for Rolling Bearings.*

ISO 281 — *Roller Bearing-Dynamic Load Ratings and Rating Life.*

ISO 10438 — *(all parts) Petroleum and natural gas industries – Lubrication, shaft-sealing and control-oil systems and auxiliaries.*

A1.2.17 **Wind gust spectra formulations**:

API RP 2A — *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms.*

Deaves D.M & Harris R.I 1978 — *A mathematical model of the structure of strong winds, CIRIA Report No. 76.*

Slettringen (Norwegian Petroleum Directorate)

A1.2.18 **Wave contour development**:

Environmental Parameters for Extreme Response: Inverse Form with Omission Factors, Winterstein et al, ISBN No. 9054103571.

A1.2.19 **Codes for concrete structures**:

BS 8110 — *Structural Use of Concrete, Parts 1, 2 and 3.*

NS 3473 — *Concrete Structures – Design Rules.*

CSA S471 — *General Requirements, Design Criteria, the Environment and Loads.*

CSA S474 — *Concrete Structures, Offshore Structures.*

ISO 19903 — *Fixed Concrete Structures.*

Other publications:

- Health and Safety Executive, Offshore Installations: *Guidance on Design, Construction and Certification*. (This guidance is no longer updated).
- Norwegian Petroleum Directorate, Guidelines relating to concrete structures to regulations relating to load bearing structures in the petroleum activities.

A1.2.20 **Subsea**:

ISO 14723 — *Petroleum and natural gas industries – Pipeline transportation systems – Subsea pipeline valves.*

ISO 13628-1 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 1: General requirements and recommendations.*

ISO 13628-2 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 2: Unbonded flexible pipe systems for subsea and marine applications.*

ISO 13628-3 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 3: Through flowline (TFL) systems.*

ISO 13628-4 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 4: Subsea wellhead and tree equipment.*

ISO 13628-5 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 5: Subsea umbilicals.*

ISO 13628-6 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 6: Subsea production control systems.*

ISO 13628-9 — *Petroleum and natural gas industries – Design and operation of subsea production systems – Part 9: Remotely Operated Tool (ROT) intervention systems.*

A1.2.21 **Miscellaneous**:

NACE MR0175/ ISO 15156 — *Petroleum and Natural gas industries materials for use in H_2S-containing environment in oil and gas production.*

ISO 19901-4 (2003) — *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations*.

ISO 15156-1 — *Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 1: General principles for selection of cracking-resistant materials.*

ISO 15156-2 — *Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons.*

ISO 15156-3 — *Petroleum and natural gas industries – Materials for use in H_2S-containing environments in oil and gas production – Part 3: Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys.*

API RP 14H — *Use of Surface Valves and Underwater Safety Valves Offshore.*

API Spec 6FA — *Fire Test for Valves.*

API Spec 6D — *Pipeline Valves (Gate, Plug, Ball and Check Valves).*

ASME B40.100 — *Pressure Gauges and Gauge Attachments.*

ISO 14224 — *Petroleum, petrochemical and natural gas industries – Collection and exchange of reliability and maintenance data for equipment.*

ISO 15663 — *Petroleum and natural gas industries – Life cycle costing.*

ISO 13637 — *Petroleum and natural gas industries – Mooring of mobile offshore drilling units (MODUS) – Design and analysis.*

ISO 13704 — *Petroleum, petrochemical and natural gas industries – Calculation of heater-tube thickness in petroleum refineries.*

WRC Bull 107 — *Welding Research Council – Local Stresses in Spherical and Cylindrical Due to External Loading.*

WRC Bull 297	*Welding Research Council – Local Stresses in Spherical and Cylindrical Shells Due to External Loading on nozzles – Supplement to WRC Bull 107.*
BS 6755	*Testing of Valves: Part 2 Specification for Fire Type-Testing Requirement.*

■ *Section A2* **Equipment categories**

A2.1 Drilling equipment

A2.1.1 A list of usual drilling equipment with its categories is given in Table A2.1.

Table A2.1 **Usual drilling equipment with its categories** (*see continuation*)

Systems and types of equipment	Category	Description of equipment
1. Well protection valves with control systems		
1.1 Blow out prevention		
1.1.1 Equipment	1A	Hydraulic connector for wellhead
	1A	Ram preventers
	1A	Annular preventers
	1B	Accumulators for sub-sea stack
	1B	Sub-sea fail-safe valves in choke and kill lines
	1A	Clamp
	1B	Test stump
1.1.2 Control equipment	1A	Electrical/electronic control systems
	1A	Deadman systems
	1A	Autoshear system
	1A	Emergency disconnect system
	1B	Accumulators in control system
	1B	Welded pipes and manifolds
	II	Unwelded hydraulic piping
	II	Flexible control hoses
	II	Hydraulic hose reel
	II	Hydraulic power unit including pumps and manifold
	II	Control pads
	1B	Acoustic transportable emergency power package
	II	Control panels
1.2 Choke and kill equipment	1A	Choke manifold
	1B	All piping to and from choke manifold
	1B	Piping for choke, kill and booster lines
	1B	Flexible hoses for choke, kill and booster lines
	1B	Valves in choke, kill and booster lines
	1B	Unions and swivel joints
	1B	Emergency circulation pump – pressure side
1.3 Diverter unit	1A	Diverter house with annular valve
	1B	Diverter piping
	1B	Valves in diverter piping
	II	Control panel
	II	Hydraulic power unit including pumps and manifold
2. Marine riser with control systems	1A	Hydraulic connector
	1A	Ball joint and flexible joint
	1A	Riser sections including joints
	1B	Support ring for riser tensioning
	1A	Telescopic joint
	1B	Accumulators
	II	Hydraulic power unit including pumps and manifold
	II	Control panel
3. Heave compensation		
3.1 Tensioning system for riser and guidelines	1B	Riser tensioner
	1B	Guideline and podline tensioners
	1B	Hydro-pneumatic accumulators
	1B	Pressure vessels
	1B	Piping system
	II	Air compressors
	II	Air dryers
	II	Wire ropes for tensioning equipment
	II	Sheaves for riser tension line
	II	Sheaves for guideline and podline
	1B	Telescopic arms for tension lines
	II	Control panels
3.2 Drill string compensator	1A	Compensator
	1B	Hydro-pneumatic accumulators
	1B	Pressure vessels
	1B	Piping system including flexible hoses
	II	Air compressor
	II	Air dryer
	II	Wire ropes
	II	Sheaves
	II	Control panels

Table A2.1 **Usual drilling equipment with its categories** (*continued*)

Systems and types of equipment	Category	Description of equipment
4. Hoisting rotation and pipe handling		
4.1 Drilling derrick	1A	Derrick and substructure
4.2 Hoisting equipment for derrick	1B	Sheaves for crown block and travelling block
	1A	Crown block including support beams
	1B	Guide track and dolly for travelling block
	1A	Travelling block
	1A	Drilling hook
	1A	Swivel
	1B	Links
	1B	Elevators
	II	Drilling line and sand line
	1B	Deadline anchor
	1B	Drawworks including foundation
	1B	Air winches for the transport of personnel
	1B	Cranes in derrick
	1B	Cherry picker
	1B	Personal hoisting equipment
4.3 Rotary equipment	1B	Rotary table including skid adopter and driving unit
	II	Kelly
	II	Master bushing
	II	Kelly bushing
	1A	Top drive
4.4 Pipe handling	1B	Racking arms with or without lifting head
	II	Finger board
	II	Tubular chute
	II	Hydraulic cathead
	II	Mousehole powered
5. Miscellaneous equipment for drilling	1B	Manual tongs for pipe handling
	II	Power tongs for pipe handling
	II	Kelly spinner
	II	Power slips
	1B	Elevators for lifting pipe
6. Bulk storage, drilling fluid circulation and cementing		
	1A	Drilling systems controls
	1B	Hydraulic control systems
	II	Hydraulic power units including ring lines
6.1 Bulk storage	1B	Pressurised storage vessels
	1B	Piping system for pressurised bulk transport
6.2 Drilling fluid, circulation and transportation		
6.2.1 Suction and transport System II (low pressure)	II	Piping systems for mixing of drilling fluid and suction line to the drilling fluid pump
	II	Centrifugal pumps for mixing drilling fluid
6.2.2 Well circulation system (high pressure)	1B	Drilling fluid pump – pressure side
	1B	Pulsation dampers
	1B	Piping circulation of drilling fluid in the well
	1B	Standpipe manifold
	1B	Rotary hose with end connections
	1B	Kelly cocks
	1B	Non-return valve in drill string (inside BCP)
	1B	Mixing pumps
	1B	Safety valves
	1B	Circulation head
6.2.3 Mud return system on deck	II	Mud return pipe
	II	Dump tank
	II	Shale shaker
	II	Drilling fluid tanks
	II	Trip tank
	II	Desander, desilter
	1B	Degasser
	1B	Piping from degasser to burners or to ventilation
	II	Chemical mixers
	II	Agitators for drilling fluid

Table A2.1 Usual drilling equipment with its categories (*conclusion*)

Systems and types of equipment	Category	Description of equipment
6.2.4 Cementing	II	Centrifugal pumps for mixing of cement
	II	Piping system for mixing cement and suction line to the cement pump
	1B	Cement pump – pressure side
	1B	Pulsation dampener
	1B	Piping for cement pump discharge
	1B	Safety valves
7. Lifting system for blow out preventer	1A	Blow out preventer crane/carrier, etc.
8. Miscellaneous equipment being part of the drilling installations	*See* Table A2.2	Miscellaneous pipes, flanges, valves, unions, etc.
	1B	Pressure vessels and separators
	1B	Heat exchangers
	1B	Pumps for overhauling of wells – pressure side
	II	Other pumps
	II	Burners
	1A	Burner boom
	See Table A2.2	Safety valves for above equipment

NOTES
1. The equipment list is intended as a guide only and does not necessarily cover all the equipment items found in a drilling plant facility.
2. Equipment considered to be important for safety which is not listed in the Table will be specially considered by LR and categorised.

A2.2 Miscellaneous equipment

A2.2.1 A list of miscellaneous equipment forming part of the drilling installation is given in Table A2.2.

Table A2.2 Miscellaneous equipment forming part of the drilling installation

Component	Conditions	Category 1B	Category II
1. Piping	Thickness of wall > 25,4 mm.	✓	
	Design temperature > 400°C	✓	
	All welded pipes and piping systems used in Category 1A and 1B piping systems	✓	
	Pipes other than those mentioned above and pipes in Category II systems		✓
2. Flanges and couplings	Standard flanges and pipe couplings		✓
	Non-standard flanges and pipe couplings used in Category 1A and 1B piping systems	✓	
	Flanges and pipe couplings other than those mentioned above, and flanges and couplings for Category II piping systems		✓
3. Valves	Valve body welded construction with ANSI rating > 600 lbs	✓	
	Valves designed and manufactured in accordance with recognised standards		✓
4. Components of high strength material	Specified yield strength > 345 N/mm^2 or tensile strength > 515 N/mm^2	✓	

A2.3 Production equipment

A2.3.1 A list of usual production equipment with its categories is given in Table A2.3.

Table A2.3 Production equipment with its categories

Systems and types of equipment	Category	Description of equipment
1. Christmas tree and sub-sea production system	1A	Christmas tree, wellhead couplings, valves and control lines
	1A	Production manifolds and piping
	1B	Template and other floor structures
	1A	Well safety valve
	II	Electrical control module
2. Riser system		
2.1 Rigid	1A	Riser sections
	1A	Hydraulic connector unit
	1A	Ball and flexible joints
	1A	Telescopic joints
	1B	Support ring for tensioning system
	1B	Valves and actuators
	II	Inflection restrictors
2.2 Flexible	1A	Flexible riser
	1A	Connectors
	1B	Buoyancy elements
3. Riser tensioning system	1B	Riser compensator
	1B	Hydro-pneumatic accumulator
	1B	Pressure vessel
	1B	Pipe system
	II	Wire ropes
	II	Sheaves
	1B	Telescopic arm for wire ropes
	II	Control panel
	II	Air compressor with drier
4. Hoisting and handling equipment for rigid riser	1A	Derrick
	1A	Crown block with supporting beams
	1A	Travelling block
	1B	Hook
	II	Wire ropes
	1B	Air tuggers for personnel
	II	Air tuggers
	1B	Loose equipment for riser handling
	1A	Crane for handling production equipment
5. Oil production/processing equipment	1B	Production manifold with valves
	1B	Separator
	1B	Heat exchanger
	1B	Gas liquid separator/cleansers
	1B	Gas compressor (pressure side)
	1B	Dehydrators
	1B	Crude oil loading pumps
	1B	Crude oil and gas metering equipment
	1B	Gas liquid separator tanks
	1B	Glycol contactor
	II	Water injection pump (pressure side)
	1B	Glycol injection pump with equipment
	1B	Oil protection and process shut-down equipment
	1B	Valves and pipes
	1A	Flare system
	1A	Pig launcher/receiver unit
	II	Instrumentation and control equipment
	1A	Swivel for production
6. Pressure vessels (general)	1B	Pressure vessels
7. Miscellaneous equipment	1A	Flare booms
	1B	Burners
	II	Instrumentation components in general
8. For well overhaul and maintenance equipment, *see* Table A2.1.	1B	Main instrumentation components and equipment in critical systems (e.g., control panels)

NOTES
1. The equipment list is intended as a guide only and does not necessarily cover all the equipment items found in a production plant facility.
2. Equipment considered to be important for safety which is not listed in the table will be specially considered by LR and categorised.

Table A2.4 Mechanical and electrical equipment and its categories for units engaged in the production, storage and offloading of liquefied gases in accordance with Part 11 (*see continuation*)

Systems and types of equipment	Category	Description of equipment
1. Mechanical and electrical equipment certification required	1A	Boil-off gas compressor
	1A	Turbo Expander
	1A	Gas heat exchanger
	1B	Burner
	1B	Flare
	1B	Cold vents
	1A	Tensioning system
	1A	Structural bearings
	1A	Cold vent boom
	1B	Offloading hose
	1A	Offloading hose end valve
	1A	Hawser strong point
	II	Pneumatic line thrower
	1B	Generators and motors over 100 kW
	1B	Uninterruptible power supplies, including battery chargers, with rating above 100 kVA
	1B	Explosion protected equipment if not carrying a certificate from a recognised test institution
	II	All other electrical equipment
	1B	Main control panels
	II	Instrumentation components
	1A	Gas turbines > 110 kW rating
	1A	Fire water pump skids (Package)
	1A	Gas compressor skid (Package)
	1A	Power generation skid
	1A	Steam turbines
	1A	Gears, shafts and couplings > 110 kW
	1A	Lifting appliances: see LR's *Code for Lifting Appliances in a Marine Environment* and hoisting and handling
	1A	Subsea facilities
	1A	Hydraulic and pneumatic power units
	1A	Flexible risers
	1A	Control umbilicals
	1A	Storage tanks over 1000 L
	1A	Fired pressure vessels
	1A	Subsea systems
	1A	Pressure vessels over 7 bar design pressure or 200ºF design temperature
	1B	Engines over 110 kW
	1A	Fire pumps and fire pump packages
	1A	Switchboards
	1A	Fixed fire-fighting system
	1A	Fixed fire and gas detection system
	1B	Utility pumps and air compressors
	1B	Expansion joint
	TA	Expansion joint in cryogenic services
	1B	Non standard valves
	1B	ESD valve and actuator
	1A	Christmas tree block and valves
	1A	HPU and pneumatic panels
	1A	Dynamic positioning system
	1B	IGS system
	1A	Cargo loading instrument
	1A	Piping for Class I and Class II and boiler superheaters
	1A	Mooring winches and windlass
	TA	Spark arrestors and vent heads, PV valves
	TA	Mooring chain
	TA	Hydraulic actuator
	TA	Anchor
	TA	GRE piping
	TA	Resins
	TA	Chokes
	1A	Winches and windlasses
	TA	Communication equipment
	TA	Fire and gas control panel and indicator
	TA	Master Mode switch
	TA	Fire hoses
	TA	Anodes

Table A2.4 **Mechanical and electrical equipment and its categories for units engaged in the production, storage and offloading of liquefied gases in accordance with Part 11** (*conclusion*)

Systems and types of equipment	Category	Description of equipment
1. Marine system equipment to be built under survey as in Pt 5, Ch 1,1	See Note	
	1A	Main propulsion engines including their associated gearing, flexible couplings, scavenge blowers and superchargers
	1A	Machinery and equipment for lowering deck structures of self-elevating units
	1A	Boilers supplying steam for propulsion or for services essential for the safety or the operation of the ship at sea, including superheaters, economisers, desuperheaters, steam heated steam generators and steam receivers. All other boilers having working pressures exceeding 3,4 bar (3,5 kgf/cm^2), and having heating surfaces greater than 4,65 m^2
	1A	Auxiliary engines which are the source of power for services essential for safety or for the operation of the ship at sea
	1A	Steering machinery
	1A	Athwartship thrust units, their prime movers and control mechanisms
	1B	All pumps necessary for the operation of main propulsion and essential machinery, e.g., boiler feed, cooling water circulating, condensate extraction, oil fuel and lubricating oil pumps
	1A	All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g., air, water and lubricating oil coolers, oil fuel and feed water heaters, de-aerators and condensers, evaporators and distiller units
	1A	Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery. Any other unfired pressure vessels for which plans are required to be submitted as detailed in Ch 11,1.6
	1A	Valves and other components intended for installation in pressure piping systems having working pressure exceeding 7,0 bar
	1A	Alarms and control systems as detailed in Pt 6, Ch 1 and Pt 7, Ch 1

NOTES

Items marked TA are to be type approved.

1. Category for gears, shafts and couplings is to be either 1A, 1B or II, depending on the category of the prime mover associated with the unit.
2. Fire water pump (directly driven) can be considered Category 1B. Fire water lift pump (not directly driven) of proven design may be accepted by conformation of material, witness of testing and review of fabrication documentation (1B). Fire water pump packages are to be built under survey (1A).
3. For complex machinery and equipment packages, categorisation and approval procedure to be agreed with on a case by case basis, considering selection of materials, service and complexity of design and fabrication method.
4. The approval procedure to be agreed with on a case by case basis, depending on function and criticality. See relevant Rule requirements, AS 4343, EC directives, Regulatory requirements, specific purchaser requirement.

Additional Notes for classed pressure vessel requirements. *See also* Pt 5, Ch 10,1.6.

Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g., air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
$pV > 600$
$p > 1$
$V > 100$
V = volume (litres) of gas or vapour space.

(b) The vessel contains liquefied gases, for fire-fighting or flammable liquids, and
$p > 7$
$V > 100$
V = volume (litres).

Guidelines on the Inspection of Positional Mooring Systems

■ *Section B1* Survey requirements

B1.1 Application

B1.1.1 The information in this Appendix is intended to provide guidance to Owners and Surveyors for the inspection of classed positional mooring systems as defined in Chapter 10.

B1.2 Annual Surveys

B1.2.1 Annual Surveys are to be carried out in accordance with Pt 1, Ch 3 with the vessel at its normal operational draft with the positional mooring system in use.

B1.2.2 The purpose of the Annual Survey is to confirm that the mooring system will continue to carry out its intended purpose until the next Annual Survey. No disruption of the unit's operation is intended. Where practicable the Annual Survey is to be carried out during a relocation move.

B1.2.3 The scope of the Annual Survey is limited to the mooring components adjacent to winches, windlasses and fairleads. Depending on the mooring component visible from the unit, particular attention should be given to:

(a) Chain:
- Wear in the chain shoulders in way of the chain stopper, windlass pockets and fairleads.
- Support of chain links in the windlass pockets.

(b) Wire rope:
- Flattened ropes.
- Broken wire.
- Worn or corroded ropes.

B1.2.4 The Surveyor should examine the maintenance records and determine if any problems have been experienced with the mooring system in the previous twelve months, e.g., breaks, mechanical damage, loose joining shackles, and chain or wire jumping.

B1.2.5 Should the Annual Survey reveal severe damage or neglect to the visible chain or cable, a more extensive survey will be required by Lloyd's Register (hereinafter referred to as 'LR').

B1.2.6 Typical damage warranting a more comprehensive survey would include:

(a) Chain:
- Reduction in diameter exceeding 75 per cent of the margin assumed in the design, *see* Ch 10,8.2.
- Missing studs.
- Loose studs in Grade 4 chain.
- Worn lifters (i.e., gypsies) causing damage to the chain.

(b) Wire rope:
- Obvious flattening or reduction in area.
- Worn cable lifters causing damage to the wire rope.
- Severe wear or corrosion.

B1.3 Special Surveys

B1.3.1 Special Periodical Surveys are to be carried out at five-yearly intervals in accordance with Pt 1, Ch 3, and will require extensive inspection, usually associated with a sheltered water visit. When considered necessary by LR the interval between Special Periodical Surveys may be reduced.

B1.3.2 The purpose of the Special Survey is to ensure that each anchor line is capable of performing its intended purpose until the next Special Survey, assuming that appropriate care and maintenance is performed in the mooring system during the intervening period.

B1.3.3 The Special Survey should include:

(a) Close visual inspection (100 per cent) of mooring chains, with cleaning as required.

(b) Enhanced representative NDT sampling.

(c) Dimension checks.

B1.3.4 Particular attention is to be given to the following:
- Cable or chain in contact with fairleads, etc.
- Cable or chain in way of winches, windlass and stoppers.
- Cable or chain in way of the splash zone.
- Cable or chain in the contact zone of the sea bed.
- Damage to mooring system.
- Extent of marine growth.
- Condition and performance of corrosion protection.

B1.3.5 This survey is to ensure that the lengths of anchor line frequently in contact with winches, windlasses and fairleads are suitably rated for this application.

B1.3.6 Joining shackles are to be examined for looseness and pin securing arrangements. All joining shackles of the Kenter type and bolted type which have been in service for more than four years should be dismantled and an MPI performed on all machined surfaces as per B2.6.3.

B1.3.7 Visual surveys of all windlass and fairlead chain pockets are to be carried out with particular attention to the following:
- Unusual wear or damage to pockets.
- Rate of wear on pockets including relative rate of wear between links and pockets.
- Mismatch between links and pockets, and improper support of the links in the pockets.

B1.3.8 The thickness (diameter) of approximately one per cent of all chain links should be measured. The selected links should be approximately uniformly distributed through the working length of the chain. The above percentage may be increased/decreased if the visual examination indicates excessive/minimal deterioration.

B1.3.9 A functional test of the mooring system during anchor-handling operation is to be carried out with particular attention given to the following:

- Smooth passageway of chain links and or/wire rope and joining shackles over the windlass and fairleads pockets.
- The absence of chain jumping or other irregularities.

B1.4 Special Continuous Surveys

B1.4.1 As an alternative to the Special Survey, the Owner may agree with LR that the Special Survey may be carried out on a continuous survey basis by providing an extra mooring line which may be regularly inspected on shore and exchanged with lines installed on the unit in accordance with an appropriate schedule.

■ *Section B2* General guidelines on inspection of mooring system components

B2.1 Anchor inspection

B2.1.1 The anchor head, flukes and shank are to be examined for damage, including cracks or bending. The anchor shackle pin should be examined and renewed if excessively worn or bent. Moveable flukes should be free to rotate.

B2.1.2 Bent flakes or shank should be heated and jacked in place according to an approved procedure, followed by Magnetic Particle Inspection.

B2.2 Anchor swivels

B2.2.1 Although swivels are no longer in common use, anchors have been lost due to corrosion of the threads engaging the swivel nut. Swivel nut threads should be carefully examined and if significant corrosion is found, the swivel should be removed or replaced.

B2.3 Chain inspection criteria

B2.3.1 This sub-Section applies only to 'Offshore' or 'Rig Quality' chains with studs secured by one of the following means:

- Mechanically locked in way of the link's flash-butt weld and fillet welded on other end (IACS R3 chain for example); or
- Studs mechanically locked in place on both ends (IACS R4 chain for example).

Other types of chain will require special consideration.

B2.3.2 The service environment of offshore mooring chain is more severe than the service environment for conventional ship anchoring chain. Offshore chain is exposed to service loads for a much longer period of time. The long-term exposure to cyclic loadings in sea-water magnifies the detrimental effect of geometric and metallurgical imperfections on fatigue life. Moreover, the increased number of links in offshore chains renders the chain more susceptible to failure from a statistical standpoint.

B2.3.3 Due to the effect of notches, e.g., the stud footprint, higher strength steels such as that used for IACS R4 chain have a lower ratio of fatigue strength to static tensile strength than typical lower strength steel such as used for IACS R3 chain.

B2.3.4 Since chain link diameter loss can be due to abrasion and corrosion, diameter measurements should be taken in the curved or bend region of the link and any area with excessive wear or gouging. Two diameter measurements should be taken 90 degrees apart. Particular attention should be given to the shoulder areas which normally contact the windlass or fairlead pockets.

Links should be rejected if the minimum cross-sectional area is less than the minimum Rule chain size plus a margin for corrosion and wear between surveys, *see* Ch 10,8.2. If repair is permitted it should be done by qualified personnel using an approved procedure.

Note

WELD REPAIR IS NOT PERMITTED ON IACS R4 CHAIN (*see* B2.3.6).

Two diameter measurements should be taken 90 degrees apart.

B2.3.5 Since studs prevent knots or twist problems during chain handling and support the sides of the links under load to reduce stretching and bending stresses, missing studs are not acceptable. Links with missing studs should be removed or the studs should be refitted using an approved procedure.

B2.3.6 Where chain studs are secured by fillet welds on one end, the stud is likely to fall out if a stud is loose or the weld is cracked. Any axial or lateral movement is unacceptable and the link must be repaired or replaced.

Links with studs fillet welded on the flash-butt weld end of the stud are unacceptable.

Rejection of links with gaps exceeding 3 mm between the stud and the link at the flash-butt weld end of the stud should be considered. Closing the gap by renewing the fillet weld may be considered but *see* the note in B2.3.8.

B2.3.7 Field repair of cracked welds should be avoided if at all possible. Welding must be performed by qualified personnel using approved procedures:

Note

WELD REPAIR IS NOT PERMITTED IN IACS R4 CHAIN.

Chains with studs mechanically locked in place on both ends may only be repaired by an approved mechanical squeezing procedure to reseat the stud.

B2.3.8 Fillet welding of studs in both ends is not acceptable; nor is welding on the stud end adjacent to the link's flash-butt weld.

Existing studs with fillet welds on both ends will require special consideration and will be subject to special crack detection methods. A reduction in mechanical properties in way of the flash-butt weld will normally be required.

B2.3.9 Where chain studs are secured by press-fitting and mechanical locking, it is very difficult to quantify excessive looseness of chain studs. The decision to reject or accept a link with a loose stud must depend on the Surveyor's judgement of the overall condition of the chain complement.

Axial movement of studs of 1 mm or less is acceptable. Links with axial movement greater than 2 mm must be replaced by squeezing or removed. Acceptance of chain links with axial movements from 1 to 2 mm must be evaluated based on the environmental conditions of the unit's location and expected period of time before the chain is again available for inspection.

Lateral movement of studs up to 4 mm is acceptable.

B2.3.10 Where links are damaged and have cracks, gouges and other surface defects (excluding weld cracks), they may be removed by grinding, provided B2.3.4 is complied with.

Links with surface defects which cannot be removed by grinding should be replaced.

Where defective links are found, they are to be removed and replaced with joining shackles, i.e., connecting links guided by the following good marine practice:

(a) The replacement joining shackle is to comply with IACS W22 or API 2F.
(b) Joining shackles are to pass through fairleads and windlasses in the horizontal plane.
(c) Since joining shackles have much lower fatigue lives than ordinary chain links, as few as possible should be used. On average, joining shackles should be separated by 120 metres or more.
(d) If a large number of links meet the discard criteria and these links are distributed in the whole chain length, the chain should be replaced with new chain.

B2.4 Fairlead and windlass inspection – Chain system

B2.4.1 Fairlead inspections should verify that all fairleads move freely about their respective pivot axes, to the full range of motion required for their proper operation. All bolts, nuts and other hardware used to secure the fairlead shafts should be inspected and replaced as required.

Fairlead attachment to the hull should be verified and NDT conducted as necessary.

NOTE

There have been cases of closing plates on the fairlead shaft coming loose due to corrosion of the threads of the securing bolts, resulting in serious damage to the fairlead arrangements and the complete jamming of the fairlead and chain. Consequently, the securing bolts should also be checked to ensure that the bolt material does not corrode preferentially should the sacrificial anode system fail to function in way of the fairlead.

B2.4.2 Special attention should be given to the holding ability of the windlasses. The chain stopper and the resultant load path to the unit's structure should be inspected and its soundness verified.

B2.4.3 It is essential that a link resting in a chain pocket makes contact with the fairlead at only the four shoulder areas of the link to avoid critical bending stresses in the link. Satisfactory chain support is to be verified, and excessive wear in the pockets should be repaired as required to prevent future damage to the chain.

B2.4.4 Chain pockets may be repaired by welding in accordance with the standard procedures supplied by the fairlead/windlass manufacturer. Normally, the hardness of the pockets should be slightly softer than the hardness of the chain link and procedures must be specific for the chain quality used.

B2.5 Fairleads and windlass – Wire rope systems

B2.5.1 Fairleads are to be inspected in accordance with B2.4.1.

B2.5.2 Special attention should be given to the holding ability of the winch and the satisfactory operation of the pawls, ratchets and braking equipment. The soundness of the resultant load path to the unit's structure should be verified.

Proper laying down of the wire on the winch drum should be verified to the satisfaction of the Surveyor and drums and spooling gear adjustments made if required.

B2.6 Inspection of miscellaneous fittings

B2.6.1 Anchor shackles, large open links, swivels and connecting links should be visually inspected. Certain areas should be examined by MPI. Areas to be examined should be clearly marked on each item. Links and fittings should be dismantled as required. Damaged items should be replaced as required by the attending Surveyor. Illustrations showing the areas of concern may be found in API RP 2I, Figure 7. General guidance on the areas requiring MPI is listed as follows:

- Large open links: the interior contact surfaces of large open links.
- Bolted shackles: the inside contact areas and the pins.
- Swivels: the swivel pin and threads and mating surface.

B2.6.2 Experience has shown that large numbers of anchors and chains are lost in service due to connecting link failure. Fatigue problems have resulted from poorly designed machined faces and corners. Joining shackles of Kenter or similar designs manufactured before 1984 are of particular concern. Joining shackles used for higher strength chains, such as ORQ and above, which do not have certificates of equivalent quality should be rejected.

B2.6.3 All joining shackles of Kenter or similar design which have been in service for more than four years should be dismantled and MPI carried out. Illustrations showing the areas of concern may be found in API RP 2I, Figure 7. General guidance in the areas requiring MPI is listed as follows:

- Joining-shackle links: all machined and ground services of the link and the sides of the curved portions of the link.
- Joining-shackle stud: machined surfaces only.
- Joining-shackle pin: 100 per cent.

Fatigue is considered to be the critical criterion in way of the machined surfaces. On the remaining surface, the profile should be ground smooth and MPI should be carried out upon completion of grinding. In general, the radius of the completed grinding operation should produce a recess with a minimum radius of 20 mm and a length along the link bar greater or equal to six times its depth.

NOTE

Sandblasting prior to MPI may change the machined surfaces and should be avoided. Alternative methods of cleaning should be used.

Where links are damaged and have cracks, gouges or other surface defects (excluding weld cracks), they may be removed by grinding, provided B2.3.4 is complied with.

Links with surface defects which cannot be removed by grinding should be replaced.

Where defective links are found, they are to be removed and replaced with joining shackles, i.e., connecting links guided by the following good marine practice:

(a) The replacement joining shackle is to comply with IACS W22 or API 2F.

(b) Joining shackles are to pass through fairleads and windlasses in the horizontal plane.

(c) Since joining shackles have much lower fatigue lives than ordinary chain links as few as possible should be used. On average, joining shackles should be separated by 120 metres or more.

(d) If a large number of links meet the discard criteria and these links are distributed in the whole chain length, the chain should be replaced with new chain.

B2.6.4 Tapered pins holding the covers of connecting links together should make good contact at both ends and the recess of counterbore at the large end of the pin holder should be solidly plugged with a peened lead slug to prevent the pin from working out.

B2.6.5 Any joining shackles of Kenter or similar designs which are loose upon reassembly should be rejected.

B2.7 Wire rope

B2.7.1 Acceptance criteria should be guided by ISO-Standard 4309-1981(E). Further insight may be gained from the discard guidance provided by API RP 2I, Figures 18 and 19.

B2.7.2 It should be borne in mind that ISO-Standard 4309-1981(E) is primarily intended for lifting appliances where the Factor of Safety may be higher than for mooring wires.

B2.7.3 The Surveyor should exercise great care in his interpretation of the condition of the wire. An obvious acceptance or rejection is comparatively easy, but the grey area between is difficult to evaluate. The Surveyor must make a sound evaluation and technical judgement based on all available evidence.

B2.7.4 In general, the age or time in service of the wire does not directly have a bearing on the acceptance or rejection of the wire other than as a factor to be taken into consideration by the Surveyor when deciding on the extent of the survey.

B2.7.5 100 per cent visual examination of wire ropes is to be carried out and diameter measurements should be performed.

B2.7.6 Visual examination should identify and record the following items for each steel wire anchor line:

(a) The nature and number of wire breaks:
- Wire breaks at the termination.
- External wear and corrosion.
- Localised grouping of wire breaks.

(b) Deformation:
- Fracture of strands.
- Termination area.
- Reduction of rope diameter, including breaking or extrusion of the core.

B2.7.7 Diameter measurements should be taken at approximately 110 metre intervals, at the discretion of the attending Surveyor. If areas of special interest are found, the survey may be concentrated on these areas and diameter measurements taken at much smaller intervals.

B2.7.8 An internal examination should be undertaken as far as practicable if there are indications of severe internal corrosion or possible breakage of the core or wire breaks in underlying areas. *See* API RP 2I, Section 2.3.6.3, for guidance on the internal inspection of wire rope.

B2.8 Guidance on wire rope damage

B2.8.1 The cause of wire rope failures may be deduced from the observed damage to the rope. The information summarised in this sub-Section covers most types of wire rope failure. More detailed information, including photographic examples, is available in ISO-Standard 4309-1981(E) and API RP 2I.

B2.8.2 Broken wires at the termination indicate high stresses at the termination and may be caused by incorrect fitting of the termination, fatigue, overloading, or mishandling during deployment or retrieval.

(a) Distributed broken wires, illustrated by Figures 9 to 12 of API RP 2I, may indicate the reason for their failure:
- Crown breaks or breakage of individual wire at the top of strands may be caused by excessive tension, fatigue, wear or corrosion.
- Excessive tension is indicated by necking down of the broken end of the wire.
- Fatigue is indicated by broken faces perpendicular to the axis of the wire.

- Corrosion and wear may be indicated by reduced cross-sections of the wire.
- Valley breaks at the interface between two strands indicate tightening of the strands, usually caused by a broken core or internal corrosion which has reduced the diameter of the core.
- Valley breaks can be caused by high loads, tight sheaves of too small a diameter.

(b) Locally grouped broken wires in a single strand or adjacent strand may be due to local damage. Once begun, this type of damage will usually get worse.

B2.8.3 Changes in rope diameter can be caused by external wear, interwire and interstrand wear, stretching or corrosion. A localised reduction in rope diameter may indicate a break in the core. Conversely, an increase in rope diameter may indicate a swollen core due to corrosion.

B2.8.4 Wear on the crown of outer strands in the rope may be caused by rubbing against fairleads, unit structure or the sea bed, depending on the location of the wear. Internal wear between individual strands and wires in the rope is caused by friction and is accelerated by bending of the rope and corrosion.

B2.8.5 Corrosion decreases rope strength by reducing the cross-sectional area and accelerates fatigue by creating an irregular surface which invites stress cracking. Corrosion is indicated by:

(a) The diameter of the rope at fairleads will grow smaller.

(b) The diameter of stationary ropes may actually grow larger, due to rust under the outer continuous layer of strands. Diameter growth is rare for mooring lines.

B2.8.6 Deformation, i.e., distortion of the rope from its normal construction, may result in an uneven stress distribution in the rope. Kinking, bending, scrubbing, crushing, and flattening are common wire rope deformations. Ropes with slight deformations will not lose significant strength. Severe distortions can accelerate deterioration and lead to premature failure.

B2.8.7 Thermal damage, although rare for mooring ropes in normal service, may be indicated by discoloration. Prompt attention should be given to damage caused by excessively high or low temperatures. The effect of very low temperatures on wire rope is unclear except for the known detrimental effect on lubricants.

■ *Cross-references*

Wire rope

API RP 2I and ISO-Standard 4309-1981(E)

(Please note comment in B2.7.2 regarding the ISO-Standard)

Chain

API RP 2I '*Recommended Practise for In-service Inspection of Mooring Hardware for Floating Drilling Units*'.

Section C1
Introduction

C1.1 Application

C1.1.1 This document has been extracted from standard LR Group Oil and Gas project Verification Work Instructions, for issue as part of the LR Quality System and should be read in conjunction with Project-Specific Quality Plan and supporting procedures. It is intended to outline appropriate scopes of survey for typical safety critical items of equipment associated with disconnectable or mobile drilling and production installations where LR is providing Certification or Verification/Validation services. The list is not exhaustive and should be used as a guide for equipment which is to be included within the scope of the service to be provided. The extent to which the Surveyors are required to attend in order to ensure that each item of equipment complies with a recognised Code, specification, or agreed Standard of performance is to be agreed with LR. The attendance required will be indicated on the supplier's Inspection and Test plan as a minimum. The procedures between Project Vendors and their local LR Surveyors are to be agreed.

C1.1.2 Some typical acceptable Codes and Standards are referenced herein. Other National or International Standards may be considered and accepted if deemed appropriate by LR. Company standards may also be applied where they represent an agreed standard of performance. *See also* Appendix A, Section 1.

C1.1.3 Where equipment is identified as being safety critical to an installation, survey/examinations undertaken within their examination schemes or codes may be considered to contribute to the validation required of such equipment. Safety critical equipment/elements are those such parts of an installation and such parts of its plant (including computer programs), or any part thereof;

(a) The failure of which could cause or contribute substantially to; or
(b) A purpose of which is to prevent, or limit the effect of, a major accident.

Section C2
Scope of survey for equipment

C2.1 Accommodation/temporary refuge units

C2.1.1 Design appraisal and survey of structure, pipework, HVAC arrangements, and fire and overpressure protection is required. *See also* C2.37 and C2.41.

C2.2 Accumulators

C2.2.1 *See* C2.29.

C2.3 Air receiver and drier vessels

C2.3.1 Where the maximum air pressure is equal to 7 barg (100 psi) or greater, a survey to Code requirements including design appraisal is required.

C2.3.2 Where the pressures are less than 100 psi, valid manufacturers' documentation can be accepted. Material is to be manufactured to a recognised pressure vessel standard.

C2.3.3 Typical acceptable standards: BS 5169, ASME VIII Div. 1 and BS 5500.

C2.4 Air winches

C2.4.1 *See* C2.33.

C2.5 Blast rated boundaries/enclosures

C2.5.1 Design appraisal for rated blast overpressure and construction under survey is required.

C2.6 Blow out preventers and BOP control unit

C2.6.1 *See* C2.57.

C2.7 Burner (flare) booms or towers

C2.7.1 Design appraisal is required with respect to:

(a) Environmental loads.
(b) Loads onto platform unit.
(c) Location and length with respect to heat radiation hazard.
(d) Construction under survey.

C2.7.2 Typical acceptable Standards are Structural Design A.I.S.C., Fabrication AWS D1.1, BS 4870, BS 4871 and Heat Radiation API RP 521.

C2.8 Coolers/chillers

C2.8.1 *See* C2.25.

C2.9 Compressors/compressor packages

C2.9.1 Reciprocating machines above 100 kW are to be built under survey with design appraisal of piping systems, any contained pressure vessels and torsional vibration characteristics for large reciprocating machines. Hydrostatic tests to be witnessed and manufacturers' data examined for other components. *See also* C2.53 and C2.55.

C2.10 Cranes

C2.10.1 *See* C2.33.

C2.11 Deluge systems

C2.11.1 Review of P&IDs, hydraulic calculations, area coverage and pump capacities is required. For survey, *see* C2.12, C2.41 and C2.45.

C2.12 Diesel prime movers

C2.12.1 For air compressors, mud pumps, cement pumps, generators and drawworks except fire.

C2.12.2 Pumps and emergency generators.

C2.12.3 Design appraisal with respect to vibration (i.e., hazardous areas), torsional vibration characteristics of shaft system and witness of commissioning of machines is required.

C2.12.4 For fire pumps, vessel propulsion, auxiliary service and emergency generators.

C2.12.5 Survey is required where the power is equal to or in excess of 100kW and to include above. If power is less than 100kW, manufacturers' documentation can be accepted. Engines should be suitably marinised, batch and line approved and able to operate under the conditions specified in LR Rules.

C2.13 Distillation plants

C2.13.1 *See* C2.25.

C2.14 Drums

C2.14.1 *See* C2.43.

C2.15 Electrical equipment

C2.15.1 Survey at manufacturers' works is not required for equipment that is not specified in LR Classification Rules requirements. Equipment must be manufactured in accordance with a recognised Standard and manufacturers' certificates are required. Flameproof and I.S. equipment is to be supplied with relevant certification and documentation issued by a recognised authority and must be suitable for the application. After installation under survey, the integrity of the complete system is to be established.

C2.16 Emergency shut-down systems/fire and gas systems

C2.16.1 Witness of testing and documentation review at suppliers' works by a specialist LR Surveyor is recommended (mandatory where full Cause and Effect Testing is not repeated during the installation commissioning phase).

C2.16.2 Design appraisal requirements will vary according to the responsibilities assigned to the supplier by the main design contractor. For programmable systems, details of Hardware, system specification and Software QA manuals will be required for review. (Process control systems do not require LR survey at suppliers' works).

C2.17 Fans

C2.17.1 Survey at manufacturers' works is not required. Manufacturers' documentation to be supplied.

C2.17.2 When intended for use in hazardous areas, fans must be of non-sparking type.

C2.18 Filters

C2.18.1 *See* C2.43.

C2.19 Fire and foam pumps

C2.19.1 *See* C2.12.

C2.20 Flare booms and towers

C2.20.1 *See* C2.7.

C2.21 Flexible hoses

C2.21.1 Manufacturers' documentation, including prototype burst testing is required. Fire test certification is generally required for hydrocarbons, high pressure and essential control service.

C2.22 Fluid transfer systems (fluid swivel type)

C2.22.1 Strength design appraisal and survey during manufacture, assembly and test is required.

C2.23 Gas turbines/compressors

C2.23.1 *See* C2.53.

C2.24 Geared machinery

C2.24.1 Witness of commissioning and testing after installation is required.

C2.25 Heat exchangers

C2.25.1 **Hydrocarbons**. Design appraisal and survey during manufacture to Code requirements is required.

C2.25.2 **Non-hydrocarbons**, Design pressures greater than or equal to 7 barg (100 psi). Design appraisal and survey during fabrication is required. *See also* C2.43, which applies equally to shell and tube exchangers.

C2.25.3 **Non-hydrocarbons**. Design pressures less than 7 barg (100 psi). Manufacturers' documentation can be accepted with hydrostatic tests being witnessed after installation. Material is to be manufactured to a recognised pressure vessel standard.

C2.25.4 Typical acceptable codes: PD 5500, ASME VIII Div. 1 & 2 and TEMA Standards.

C2.26 Helideck

C2.26.1 Design appraisal of structure, markings, lights, obstacle free/drop off zones, fire and escape arrangements is required. Survey under fabrication as for modules.

C2.27 Hoists

C2.27.1 *See* C2.33.

C2.28 Hydrocyclones

C2.28.1 Survey at manufacturers' works is not required for proprietary drilling equipment.

C2.28.2 *See* C2.43.

C2.29 Hydro-pneumatic accumulators – Manifolds, fluid reservoirs

C2.29.1 Design appraisal and construction under survey is required.

C2.29.2 Typical acceptable standards: BS 5045 and ASME VIII Div. 1.

C2.30 Impressed current CP system

C2.30.1 Design appraisal. Survey of installation, witness test and commissioning are required.

C2.31 Inert gas generator

C2.31.1 Design appraisal and survey at manufacturers' works. Witness test and commissioning are required.

C2.32 Lifeboats, TEMPSCs, rescue craft and davits

C2.32.1 Design appraisal and survey at manufacturers' works. Witness test and commissioning are required.

C2.33 Lifting appliances and cranes

C2.33.1 To be built under survey in accordance with the LR's Code for Lifting Appliances in a Marine Environment, which would include design appraisal, material identification, weld procedures and welder qualification tests, approval of NDT procedures and testing on completion. Care is to be taken that the appliance is suitable for use under dynamic loading offshore.

C2.33.2 Air winches (non-personnel). No survey required at source. Manufacturers' documentation will be accepted provided it includes evidence of hydrostatic test of pressure parts.

C2.33.3 Cranes mountings, including pedestals. Design appraisal and construction under survey is required. Witness of testing and commissioning after installation is also required.

C2.33.4 Other typical acceptable construction codes are given in Appendix A1.2.13.

C2.33.5 Personnel hoist. Design appraisal and construction under survey is required. Witness of testing and commissioning after installation is also required.

C2.33.6 Other lifting devices. Where LR Certification is required by the client, design appraisal and survey with load testing after installation on the platform/unit is required.

C2.33.7 Other lifting devices. Where LR Certification is not required, inspection and testing at the manufacturers' works is required only for devices with a capacity greater than or equal to 10 tonnes. Devices with a capacity of less than 10 tonnes can be accepted if presented with valid manufacturers' documentation. In addition, they must be tested after installation.

C2.34 Loading instrument

C2.34.1 To be verified for LR Classification compliance – *see* Part 1. Hardware to be type approved for marine use.

Guidelines on Scope of Survey Certification of Safety Critical Equipment

C2.35 Manifolds, choke, production, test, etc.

C2.35.1 Design appraisal and survey is required.

C2.35.2 Typical acceptable standards: ANSI B3 1.3.

C2.36 Metering packages and equipment

C2.36.1 To be built under survey with design appraisal of piping systems aspects and any pressure vessels. Hydrostatic test to be witnessed and manufacturers' data examined for all other aspects.

C2.37 Modules (all types)

C2.37.1 Design appraisal and survey of structure during construction is required and the following loads should be considered in the design.
(a) Environmental.
(b) Equipment and operational weights.
(c) Construction, including lifting case.

C2.37.2 *See also* C2.41.

C2.38 Mooring systems (floating installations)

C2.38.1 Structural. Design appraisal and survey during manufacture is required for all components, including anchors, cables, chains, turret structure, etc.

C2.38.2 Machinery. Design appraisal is required for all main bearings, mooring winches and chain stoppers.
NOTE:
Quayside mooring equipment can be accepted on the basis of manufacturers' documentation.

C2.39 Offloading systems

C2.39.1 *See* C2.21, C2.41 and C2.46.

C2.39.2 Strength design appraisal of mooring winches, breakaway couplings, etc., is required.

C2.40 Pig launchers and receivers

C2.40.1 *See* C2.43.

C2.41 Pipework and fittings

C2.41.1 All fabricated pipework, e.g., process systems, gas and liquid fuel systems, fire main, compressed air lines, hydraulic systems, mud systems, etc., will be subject to design appraisal and survey during fabrication. Pipe fittings will normally be accepted with manufacturers' documentation, but significant fabricated items may require survey at manufacturers' works. Fabricated saddles for use in the fire main should be supplied with a copy of a valid proof test certificate.

C2.41.2 The survey must include:
(a) Review of QA/QC system.
(b) Examination at works during fabrication and test.
(c) Review and acceptance of weld procedures and welder qualification tests.
(d) Review and acceptance of NDT procedures.
(e) Verification of materials against relevant mill certificates.
(f) Appraisal of P&IDs, material and pipe schedules.

C2.41.3 Where pipework is included as part of a package, it is to be surveyed as above.

C2.41.4 Typical acceptable standards: ANSI B3 1.3.

C2.42 PLCs/programmable electronic systems

C2.42.1 Hardware to be type approved for offshore use. Software to be developed under suitable software QA system. LR to witness commissioning tests.

C2.43 Pressure vessels

C2.43.1 (Separators, knockout drums, pulsation dampers, etc., including auto sprinkler and fire-extinguishing storage systems).

C2.43.2 Where the system gauge pressure in bar multiplied by the internal volume in litres exceeds 200, vessels are to be built under survey which would include design appraisal, material identification, weld procedure and welder qualification tests and approval of NDT procedures. The vessel is to be built in accordance with a recognised Code or Standard and subject to hydrostatic test and internal examination on completion.

C2.43.3 Typical acceptable codes: PD 5500 and ASME VIII.

C2.44 Process equipment (bulk)

C2.44.1 All equipment, whether installed initially or at a subsequent date, should be manufactured to a relevant Code, Standard or specification and written confirmation of this, together with appropriate test certificates, should be obtained from the manufacturer. *See* C2.41 and the remainder of this appendix for individual equipment items.

C2.45 Pumps – Fire, water deluge, foam, etc.

C2.45.1 All fire-fighting pumps (and prime movers) to be built under survey.

C2.45.2 Material certificates and certificates for hydrostatic testing of cast casings, etc., to be reviewed.

C2.46 Pumps for other services

C2.46.1 Survey at manufacturers' works for verification purposes is not required. Manufacturers' documentation including material certificates is to be supplied.

C2.47 Radio tower

C2.47.1 Design appraisal will be required only in respect of:

(a) Environmental loads.
(b) Loads transmitted to the structure.
(c) Location relating to the helideck.

C2.47.2 No fabrication inspection is required.

C2.48 Regenerators and absorbers, glycol – (fired) boilers and steam receivers – (fired)

C2.48.1 Design appraisal and survey is required, *see also* C2.43 and C2.25.

C2.49 Separators

C2.49.1 *See* C2.43.

C2.50 Steel – Plate, rolled sectors, tubulars and pipe

C2.50.1 For certification, inspection/validation at mill in accordance with a recognised Standard and specification is required on all material for primary structures. However, certification of other IACS members will in general be acceptable.

(a) Jackets including conductor framing.
(b) Piles.
(c) Any secondary steel that is connected directly to the primary structure.
(d) Any structural steel utilised for the load-bearing framework of the module.
(e) Where floors contribute to the strength and integrity of the module. Where steel is procured from steelworks approved by LR, our scope will normally be limited to witness of mechanical testing and check of results against agreed specifications. In the event of primary steel being procured from stockists, LR involvement will normally consist of verification of test certificates, material identification and confirmation of properties against agreed specifications.

C2.50.2 Materials for secondary structures need not be inspected at source provided the material is manufactured in accordance with a recognised Standard and is supported by manufacturers' valid mill certificates.

C2.50.3 Examples of secondary structures include gangways, walkways, handrails, cladding, helideck, floors, pipe supports, equipment plinths, mud and similar tanks and installation aids.

C2.51 Strainers

C2.51.1 *See* C2.43.

C2.52 Tanks

C2.52.1 Dry mud, barytes, bulk cement, chemicals:

(a) Design appraisal and survey is required if the above tanks are to be subjected to any positive or negative pressure conditions.
(b) If not pressurised, the Surveyors may accept a Third Party Inspection Certificate with evidence of testing for the purpose intended.

C2.52.2 Non hazardous liquid storage tanks – Open, vented or hydrostatic head only. Third party Inspection Certificate with evidence of construction and testing to a recognised Code or specification is required.

C2.52.3 Pressurised lubricating oil or seal-oil tanks. Design appraisal and survey is required.

C2.52.4 Fuel tanks and hazardous liquid tanks. Design appraisal and survey is required. Typical acceptable standards: BS 799 part IV and BS 2654.

C2.53 Turbines and compressors

C2.53.1 Design pressure greater than or equal to 7 barg (100 psi). Surveyor is to verify manufacturers' documentation, witness hydraulic tests of pressure parts and commissioning of machines.

C2.53.2 Design pressure less than 7 barg (100 psi). Surveyor is to verify manufacturers' documents and witness commissioning. Material is to be manufactured to a recognised pressure vessel standard.

C2.53.3 Gas turbines. Consideration should be given to the codes used for pressure-retaining components and the need for containment, with a view to minimising and localising damage in the event of rotor blade failure. Survey of fabricated pressure-retaining items will generally be required.

C2.54 Umbilicals for subsea completion control systems

C2.54.1 Design appraisal and survey at source to include review of manufacturing and quality plans is required. Witness of factory acceptance tests and documentation review is also required.

C2.55 Valves including emergency shut-down and safety valves

C2.55.1 In general, valves and fittings need not be surveyed at source provided they are manufactured in accordance with a recognised Code or Standard and are identifiable with a manufacturers' certificate which includes the materials used for pressure-containing parts.

C2.55.2 Details of certain large valves and fittings of welded construction will require to be submitted for special consideration, (e.g., Riser ESDVs, SSIVs, etc.). Design appraisal and survey of these items will be required in most cases.

C2.55.3 Testing of pressure relief valves to be witnessed during commissioning at fabrication sites.

C2.55.4 Typical acceptable standards: Safety Valve Design API RP 520, Valves API 6 series, B55351 and Fittings BS 1640.

C2.56 Ventilation and pressurisation systems including fire dampers

C2.56.1 Design appraisal: hazardous area zones and structural fire protection. The systems are to be surveyed and tested during installation and commissioning.

C2.56.2 Fire Dampers are to be type approved.

C2.57 Well control equipment

C2.57.1 Independent Review Certificate from a Certifying Authority is to be issued for manufacture and design. Surveyors will issue a Certificate of Conformity following completion of the equipment and when satisfied that the equipment has been built and tested in accordance with the approved Specification for Manufacture. Manufacturers' records of materials, inspection and tests should be assessed by the Surveyor.

C2.57.2 For Verification (Wells Examination). Well control equipment will be subject to a design examination and survey during construction/assembly and testing where the equipment is designated as safety critical to the Installation.

C2.57.3 Work done by others to meet the requirements of the well examination scheme will contribute to verification.

C2.58 Well control panel

C2.58.1 Design appraisal and survey, as for pipework and fittings.

C2.59 Winches

C2.59.1 *See* C2.33.

C2.60 Xmas trees

C2.60.1 *See* C2.58.

Rules and Regulations for the Classification of Offshore Units

Part 4
Steel Unit Structures

July 2014

Lloyd's Register

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■ *Section 1* Rule application

1.1 General

1.1.1 The Rules, in general, apply to steel units of all welded construction. The use of other materials in the structure will be specially considered. For concrete structures, *see* Part 9. The Rules apply to the unit types defined in Parts 1 and 3. Units of unconventional design will receive individual consideration based on the general standards of the Rules.

1.2 Loading

1.2.1 The Rules are framed on the understanding that units will be properly loaded and operated. Units are to be operated in accordance with an Operations Manual which is to contain all the necessary information for the safe loading and operation of the unit, *see* Pt 3, Ch 1,3.

1.2.2 All ship units and other surface type units are to be provided with loading guidance information containing sufficient information to enable the loading, unloading and ballasting operations and inspection/maintenance of the unit within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in Pt 3, Ch 4,8 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). *See also* Pt 1, Ch 2,1.4.5 and 1.4.6.

1.2.3 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided, the system is to be certified in accordance with LR's *Approval of Longitudinal Strength and Stability Calculation Programs*.

1.3 Advisory services

1.3.1 The Rules do not cover certain technical characteristics such as stability, trim, vibration, docking arrangements, etc. The Classification Committee cannot assume responsibility for these matters, but is willing to advise upon them on request.

1.4 Intact and damage stability

1.4.1 New units will be assigned class only after it has been demonstrated that the level of intact and damage stability is adequate, *see* Pt 1, Ch 2,1.

1.4.2 For classification purposes, the minimum requirements for watertight and weathertight integrity are to comply with Chapter 7.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be submitted in support of alternative arrangements and scantlings. LR may undertake independent calculations to check the calculations submitted by the designers.

2.2 Equivalents

2.2.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

2.2.2 Where direct calculation procedures are employed supporting documentation is to be submitted for appraisal and this is to include details of the following:

- Calculation methods, assumptions and references.
- Loading.
- Structural modelling.
- Design criteria and their derivation, e.g., permissible stresses, factors of safety against plate panel instability, etc.

2.2.3 LR will be ready to consider the use of Builders' programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.

(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

Section 3
National and International Regulations

3.1 International Conventions

3.1.1 The Committee, when authorised, will act on behalf of National Administrations and, if requested, LR will certify compliance in respect of National and International Statutory Safety and other requirements for offshore units.

3.1.2 In satisfying the Load Line Conventions, the general structural strength of the unit is required to be sufficient for the draught corresponding to the freeboards to be assigned. Units built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Conventions.

3.2 International Association of Classification Societies (IACS)

3.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

3.3 International Maritime Organization (IMO)

3.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in these Rules and Regulations.

Section 4
Information required

4.1 General

4.1.1 In general, the plans and information required to be submitted are given in 4.2.

4.1.2 Requirements for additional plans and information for functional unit types are given in Part 3.

4.1.3 Plans are generally to be submitted in triplicate, but only one copy of supporting documents and calculations will be required.

4.2 Plans and supporting information

4.2.1 Plans covering the following items are to be submitted for approval, as relevant to the type of unit:
- Bilge keel details.
- Bracings and associated primary structure.
- Corrosion control scheme.
- Deck structures including pillars and girders.
- Double bottom construction.
- Engine room construction.
- Equipment and supports.
- Erection sequence.
- Footings, pads or mats.
- Fore and aft end construction.
- Helideck.
- Ice strengthening.
- Leg structures and spuds.
- Loading manuals, preliminary and final.
- Machinery seatings.
- Main hull or pontoon structure.
- Masts and derrick posts.
- Materials and grades.
- Midship sections showing longitudinal and transverse material.
- Penetrations and attachments to primary structure.
- Profile and decks.
- Quality control and non-destructive testing procedures.
- Riser support structures.
- Rudder, stock, tiller and steering nozzles.
- Shell expansion.
- Stability columns.
- Stern frame and propeller brackets.
- Structural categories.
- Structural bulkheads and flats.
- Structure in way of jacking or elevating arrangements.
- Superstructures and deckhouses.
- Support structures for cranes, masts, derricks, flare towers and heavy equipment.
- Tank boundaries and overflows.
- Tank testing procedures and schedules.
- Temporary anchoring equipment.
- Towing arrangements and equipment.
- Transverse and longitudinal sections showing scantlings.
- Watertight sub-division.
- Watertight and oiltight bulkheads and flats.
- Watertight and weathertight doors and hatch covers.
- Welding details and procedures.

4.2.2 The following supporting plans and documents are to be submitted:
- General arrangements showing decks, profile and sections indicating all major items of equipment and machinery.
- Calculation of equipment number.
- Capacity plan.
- Cross curves of stability.
- Cross curves of allowable V.C.G.
- Design deck loading plan.
- Dry-docking plan.
- Operations Manual, *see* Pt 3, Ch 1,3.
- Tank sounding tables.
- Wind heeling moment curves.
- Lines plan or equivalent.

4.3 Calculations and data

4.3.1 The following calculations and information are to be submitted where relevant to the unit type and its design:

- Proposed class notations, operating areas and modes of operation, list of operating conditions stating proposed draughts.
- Design environmental criteria applicable to each mode, including wind speed, wave height and period, or sea state/wave energy spectra (as appropriate), water depth, tide and surge, current speed, minimum air temperature, ice and snow loads, sea bed conditions.
- A summary of weights and centres of gravity of lightship items.
- A summary of all items of deadweight, deck stores/supplies, fuel, fresh water, drill water, bulk and sack storage, crew and effects, deck loads (actual, not design allowables), riser, guideline, mooring tensions, hook or derrick loads and ballast schedules. The summary should be given for each operating condition.
- Details of distributed and concentrated gravity and live design loadings including crane overturning moments.
- Tank content data, and design pressure heads.
- Details of tank tests, model tests, etc.
- Strength and fatigue calculations.
- Calculation of hull girder still water bending moment and shear force as applicable.
- Calculation of hull girder section modulus at midships and elsewhere as required by LR. Additional calculations to verify longitudinal strength may be required when:
  - (a) The maximum hogging and sagging combined still water and vertical wave bending moments do not occur at midship.
  - (b) The structural arrangement at midship changes to a different arrangement within the 0,4*L* midship region.
- Stability calculations for intact and damaged cases covering a range of draughts to include all loading conditions.
- Documentation of damage cases, watertight sub-division and limits for downflooding.
- Freeboard calculation.

4.4 Specifications

4.4.1 Adequate design specifications in appropriate detail are to be submitted for information.

4.4.2 Specifications for the design and construction of the hull and structure are to include materials, grades/standards, welding construction procedures and fabrication tolerances.

4.4.3 Specifications related to the unit's proposed operations are to include environmental criteria, modes of operation and a schedule of all model tests with reports on minimum air gap, motion predictions, mooring analysis, etc.

4.5 Plans to be supplied to the unit

4.5.1 The following plans and documents are to be placed on board the unit, *see* Pt 3, Ch 1,2:

- Operations Manual.
- Loading Manual.
- Construction Booklet.
- Main scantlings plans.
- Corrosion control system.

4.5.2 Where an **OIWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in Pt 3, Ch 1,2 are also to be placed on board.

4.5.3 Where a ShipRight **CM** (Construction Monitoring) notation or descriptive note is to be assigned, the approved Construction Monitoring Plan (CMP), as detailed in the *ShipRight Construction Monitoring Procedures*, is to be maintained on board the unit.

■ *Section 5* Definitions

5.1 General

5.1.1 **Rule length, *L*,** in metres, for self-elevating units and semi-submersible units with twin lower hulls is to be taken as 97 per cent of the extreme length on the maximum design transit waterline measured on the centreline or on a projection of the centreline, *see* Fig. 1.5.1.

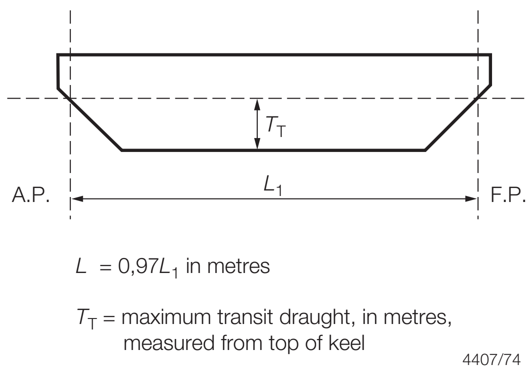


Fig. 1.5.1
Rule length for self-elevating units and semi-submersible units with twin lower hulls

5.1.2 The **Rule length, *L*,** for ship units and other surface type units is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. *L* is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In ships with unusual stem or stern arrangements the Rule length, *L*, will be specially considered.

5.1.3 The Rule length for units with unconventional form will be specially considered in relation to the transit or operating waterlines.

5.1.4 **Breadth, *B***, is the greatest moulded breadth, in metres.

5.1.5 **Depth, *D***, is measured, in metres, at the middle of the length, *L*, from the top of keel to top of the deck beam at side on the uppermost continuous deck.

5.1.6 **Draught, T_0**, is the maximum design operating summer draught, in metres, measured from top of keel.

5.1.7 **Draught, T_T**, is the maximum design transit summer draught, in metres, measured from top of keel.

5.1.8 The **block coefficient, C_b**, is the moulded block coefficient corresponding to the maximum design draught *T* based on the Rule length *L* and moulded breadth *B* as follows:

$$C_b = \frac{\text{Moulded displacement (m}^3\text{) at draught } T}{LBT}$$

where

$T = T_0$ for ship units and other surface type units

$T = T_T$ for self-elevating and semi-submersible units.

5.1.9 In general, the forward perpendicular, F.P., is the perpendicular at the intersection of the waterline at the draught *T* with the fore end of the hull. The aft perpendicular, A.P., is the perpendicular at the intersection of the waterline at the draught *T* with the aft end of the hull, *see also* 5.1.2.

5.1.10 Amidships is to be taken as the middle of the Rule length, *L*, measured from the forward side of the stem or hull.

5.1.11 **Lightweight** is defined as the weight of the complete unit with all its permanently installed machinery, equipment and outfit, including permanent ballast, spare parts normally retained on board, and liquids in machinery and piping to their normal working levels, but does not include liquids in storage or reserve supply tanks, items of consumable or variable loads, stores or crew and their effects.

■ *Section 6* Inspection, workmanship and testing

6.1 General

6.1.1 Requirements regarding inspection, workmanship and testing are given in Pt 3, Ch 1,8 of the Rules for Ships and Ch 13,2 of the Rules for Materials and should be complied with. For ship units, testing load heights are to be in accordance with Pt 10, Ch 2,2.3.

Section

Section 1
Materials of construction

1.1 General

1.1.1 The Rules relate in general to the construction of steel units, although consideration will be given to the use of other materials. For the use of aluminium alloys, *see* 1.3.

1.1.2 The materials used in the construction of the unit are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary, *see also* Pt 3, Ch 1,4.

1.1.3 The requirements for materials for use in liquefied gas containment systems are specified in Part 11 of these Rules.

1.1.4 For concrete structures, *see* Pt 9, Ch 4.

1.2 Steel

1.2.1 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

1.2.2 When higher tensile steel is used in the construction of the unit the local scantlings determined from the Rules for steel plating, longitudinals, stiffeners and girders, etc., may be based on a *k* factor determined as follows:

$$k = \frac{235}{\sigma_o} \left(k = \frac{24}{\sigma_o} \right)$$

or 0,66, whichever is the greater

where

σ_o = specified minimum yield stress, of the higher tensile steel in N/mm^2 (kgf/mm^2).

1.2.3 When higher tensile steel is used in the primary structure of ship units, the determination of the hull girder section modulus is to be based on a higher tensile steel factor k_L determined in accordance with Table 2.1.1.

Table 2.1.1 Values of k_L

Specified minimum yield stress In N/mm^2 (kgf/mm^2)	k_L
235 (24)	1,0
265 (27)	0,92
315 (32)	0,78
355 (36)	0,72
390 (40)	0,66
460 (47)	0,62

NOTES
1. Intermediate values by linear interpolation.
2. For the purpose of calculating hull moment of inertia as specified in Pt 3, Ch 4,5.8.1 of the Rules for Ships, k_L=1,0.

1.2.4 For the application of the requirements of 1.2.2 and 1.2.3, special consideration will be given to steel where σ_o > 355 N/mm^2 (36 kgf/mm^2). Where such steel grades are used in areas which are subject to fatigue loading, the structural details are to be verified using fatigue design assessment methods.

1.2.5 Where steel castings or forgings are used for major structural components, they are to comply with Chapter 4 or Chapter 5 of the Rules for Materials, as appropriate.

1.3 Aluminium

1.3.1 The use of aluminium alloy is permitted for superstructures, deckhouses, hatch covers, helicopter platforms, or other local components on board offshore units, except where stated otherwise in Pt 3, Ch 1,4.5.

1.3.2 Except where otherwise stated, equivalent scantlings are to be derived as follows:

Plating thickness:

$$t_a = t_s \sqrt{k_a}\ c$$

Section modulus of stiffeners:

$$Z_a = Z_s\, k_a\, c$$

where

c = 0,95 for high corrosion resistant alloy
= 1,0 for other alloys

$$k_a = \frac{235}{\sigma_o}$$

t_a = thickness of aluminium plating
t_s = thickness of mild steel plating
Z_a = section modulus of aluminium stiffener
Z_s = section modulus of mild steel stiffener
σ_a = 0,2 per cent proof stress or 70 per cent of the ultimate strength of the material, whichever is the lesser.

Table 2.1.2 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm²		Ultimate tensile strength, N/mm²	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (*see* Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (*see* Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. *See also* Table 8.1.3 or Table 8.1.4 in Chapter 8 of the Rules for Materials.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5 of the Rules for Materials.
4. Where detail structural analysis is carried out, 'Unwelded' stress values may be used away from heat affected zones and weld lines, *see also* 1.3.3.
5. For thickness less than 12,5 mm the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm² and the minimum tensile strength is to be taken as 315 N/mm².

1.3.3 In general, for welded structure, the maximum value of σ_a to be used in the scantlings derivation is that of the aluminium in the welded condition. However, consideration will be given to using unwelded values depending upon the weld line location, or other heat affected zones, in relation to the maximum applied stress on the member (e.g., extruded sections).

1.3.4 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 2.1.2.

1.3.5 Where strain hardened grades (designated Hxxx) are used, adequate protection by coating is to be provided to avoid the risk of stress corrosion cracking.

1.3.6 The use of aluminium alloy for primary structure will be specially considered.

■ *Section 2* Structural categories

2.1 General

2.1.1 For the determination of steel grades in accordance with 4.1, all structural components of the unit may be grouped into structural categories taking into account the following aspects:

(a) Applied loading, stress level and the associated stress pattern.
(b) Critical load transfer points and stress concentrations.
(c) Consequence of failure.

2.1.2 The structural categories can be summarised as follows:

(a) **Special structure**:
Primary structural elements which are in way of critical load transfer points and stress concentrations.

(b) **Primary structure**:
Structural elements essential to the overall integrity of the unit.

(c) **Secondary structure**:
Structural elements of less importance than primary structure, failure of which would be unlikely to affect the overall integrity of the unit.

2.1.3 For the structural categories of supporting structures of drilling plant and production and process plant, *see* Pt 3, Ch 7,2.2 and Ch 8,2.2 respectively.

2.2 Column-stabilised and tension-leg units

2.2.1 In general, the structural members of column-stabilised and tension-leg units are to be grouped into the following structural categories:

(a) **Special structure**:
- (i) The plating of decks, heavy flanges, shell boundaries and bulkheads of the upper hull or platform which form 'box' or 'I' type supporting structure in way of critical load transfer points and which receive major concentrated loads.
- (ii) The shell plating in way of the intersections of vertical columns with platform decks and upper and lower hulls.
- (iii) End connections and major intersections of primary bracing members.
- (iv) Critical load transfer by 'through' material used at connections of vertical columns, upper platform decks and upper or lower hulls which are designed to provide proper alignment and adequate load transfer.
- (v) External brackets, portions of bulkheads, flats, and frames which are designed to receive concentrated loads at intersections of major structural members.
- (vi) Structure supporting concentrated mooring loads.

(b) **Primary structure**:
- (i) The plating of decks, heavy flanges, shell boundaries and bulkheads of the upper hull or platform which form 'box' or 'I' type supporting structure except where the structure is considered as special application.
- (ii) The shell plating of vertical columns, lower and upper hulls, and diagonal and horizontal braces.
- (iii) Bulkheads, flats or decks, stiffeners and girders which provide local reinforcement or continuity of structure in way of intersections, except areas where the structure is considered as special application.
- (iv) Main support structure to cantilevered helicopter decks and lifeboat platforms.
- (v) Heavy substructures and equipment supports, e.g., drillfloor substructure, crane pedestals, anchor line fairleads and their supporting structure, *see also* 2.1.3.
- (vi) Riser support structure.

(c) **Secondary structure**:
- (i) Upper platform decks or decks of upper hulls, except areas where the structure is considered as primary or special application.
- (ii) Bulkheads, stiffeners, flats, decks, girders and web frames in vertical columns, upper and lower hulls, diagonal and horizontal bracing, which are not considered as primary or special application.
- (iii) Helicopter platforms and deckhouses.
- (iv) Lifeboat platforms.

2.3 Self-elevating units

2.3.1 In general, the structural members of self-elevating units are to be grouped into the following categories:

(a) **Special structure**:
- (i) Vertical columns in way of intersections with the mat structure.
- (ii) Intersections of lattice type leg structures which incorporate novel construction, including the use of steel castings.
- (iii) Leg to spudcan connections.
- (iv) Jack-house or bulkheads supporting locking.

(b) **Primary structure**:
- (i) The plating of bulkheads, decks and shell boundaries of the main hull or platform which in combination form 'box' or 'I' type main supporting structure.
- (ii) External plating of cylindrical legs.
- (iii) Plating of all components of lattice type legs.
- (iv) Jack-house supporting structure.
- (v) External shell plating of footings and mats and structural components which receive initial transfer of loads from the leg structures.
- (vi) Internal bulkheads and girders of supporting structure of footings and mats which are designed to distribute major concentrated or uniform loads into the structure.
- (vii) Main support structure to cantilevered helicopter decks and lifeboat platforms.
- (viii) Heavy substructures and equipment supports, e.g., drillfloor substructure, drilling cantilevers and crane pedestals, *see also* 2.1.3.

(c) **Secondary structure**:
- (i) Deck and shell boundaries of the main hull or platform, except where the structure is considered as primary application.
- (ii) Internal bulkheads, decks stiffeners and girders of the main hull structure, except where the structure is considered as primary structure.
- (iii) Internal diaphragms, girders or stiffeners in cylindrical legs.
- (iv) Internal bulkheads, stiffeners and girders of footings and bottom mat supporting structures, except where the structure is considered primary or special application.
- (v) Helicopter platforms and deckhouses.
- (vi) Lifeboat platforms and walkways.

2.4 Ship units and other surface type units

2.4.1 Material classes and steel grades for individual areas of the hull structure of ship and barge type units are to comply

with Pt 3, Ch 2,2 of the Rules for Ships.

2.4.2 Where the minimum design temperature, *see* 3.1, for exposed structure is –5°C or below, or for structural components not addressed by 2.4.1, the requirement of 2.4.3 should be complied with and the steel grades should be assigned in accordance with Table 2.4.1.

2.4.3 In general, the structure of ship units and other surfaces type units is to be grouped into the following structural categories:

(a) **Special structure**:
- (i) Structure in way of critical load transfer points which are designed to receive major concentrated loads in way of mooring systems, including yokes and similar structures, and supports to hawsers to mooring installations including external hinges, complex padeyes, brackets and supporting structures.
- (ii) Sheerstrake or rounded gunwale.
- (iii) Stringer plate at strength deck.
- (iv) Deck strake at longitudinal bulkheads.
- (v) Bilge strake.
- (vi) Continuous longitudinal hatch coamings.

(b) **Primary structure**:
- (i) Strength deck and raised quarter deck plating except where categorised '**special**'.
- (ii) Bottom shell plating of the main hull except where categorised '**special**'.
- (iii) Bulkhead plating in way of moonpools, drilling wells and circumturret.
- (iv) Upper strake in longitudinal bulkheads.
- (v) Continuous longitudinal members above strength deck except where categorised '**special**'.
- (vi) Vertical strake (hatch side girder) and upper sloped strake in top wing tanks.
- (vii) Main support structure to cantilevered helicopter decks and lifeboat platforms.
- (viii) Heavy substructures and equipment supports, e.g. integrated support stools to process plant, drill floor substructure, crane pedestals, anchor line fairleads and chain stoppers for positional mooring systems and their supporting structures, *see also* 2.1.3.
- (ix) Riser support structures.
- (x) Turret bearing support structure.
- (xi) Swivel stack support structure.
- (xii) Supporting structures to external turret.

(c) **Secondary structure**:
- (i) Bulkhead plating, side shell, longitudinals, stiffeners, deck plating including poop deck and forecastle deck, flats, girders and web frames, etc., except where the structure is categorised as **special** or **primary** structure. For topside plant supporting structures, *see also* 2.1.3.
- (ii) Helicopter platforms and deckhouses.
- (iii) Lifeboat platforms, walkways, guard rails, minor fittings and attachments, etc.

2.5 Buoys, deep draught caissons, turrets and miscellaneous structures

2.5.1 In general, the structure of buoys, deep draught caissons, turrets, and other miscellaneous structures included in Pt 3, Ch 13 is to be grouped into the following structural categories:

(a) Special structure:
- (i) Structure in way of critical load transfer points which are designed to receive major concentrated loads including external brackets, portions of bulkheads, flats and frames.
- (ii) Intersections of structures which incorporate novel construction including the use of steel castings.
- (iii) Complex padeyes.
- (iv) Highly stressed structural elements of anchor-line attachments.
- (v) Bearings and structure at the base of mooring towers.

(b) Primary structure: The following structural members are categorised as primary, except when the structure is considered as special application:
- (i) External shell plating of buoys, deep draught caissons, turrets and subsea modules.
- (ii) Strength decks of buoys and deep draught caissons.
- (iii) Truss structure supporting decks on deep draught caissons.
- (iv) Miscellaneous structures:
  - Support stools to process plant.
  - Bearing support structure.
  - Swivel stack support structure.
  - Turntable construction.
  - Chain tables.
  - Riser support structure.
  - Hawser support structure.
  - Yoke and mooring arm construction.
  - Mooring towers.
- (v) Main support structures to cantilevered helideck and lifeboat platforms.
- (vi) Heavy substructures and equipment supports, e.g., crane pedestals, anchor line fairleads for positional moorings, chain stoppers and their supporting structures.
- (vii) Boundary bulkheads of moonpools.

(c) Secondary structure:
- (i) Bulkheads, stiffeners, decks, flats, etc., except where the structure is categorised as Special or Primary structure. For topside structures, *see also* 2.1.3.
- (ii) Helicopter platforms and deckhouses.
- (iii) Lifeboat platforms, walkways, guard rails and minor fittings and attachments, etc.

Section 3
Design temperature

3.1 General

3.1.1 The Minimum Design Temperature (MDT) is a reference temperature used as a criterion for the selection of the grade of steel to be used in the structure and is to be determined in accordance with Pt 3, Ch 1,4.

3.1.2 The MDT is not to exceed the lowest service temperature of the steel as appropriate to the position in the structure.

3.1.3 A design temperature of 0°C is generally acceptable for determining the steel grades for structure which is normally underwater, *see also* 4.1.4.

3.1.4 For column-stabilised units of conventional design, the lower hulls need not normally be designed for a design temperature lower than 0°C.

3.1.5 The design temperature for internal structure of all units is to be separately defined, *see* Lloyd's Register's *Provisional Rules for the Winterisation of Ships*.

3.1.6 Internal structures in way of permanently heated compartments need not normally be designed for temperatures lower than 0°C.

Section 4
Steel grades

4.1 General

4.1.1 The grades of steel to be used in the structure are, in general, related to the thickness of the material, the structural category and the MDT. The grades of steel to be used in the construction of the unit are to be determined from Table 2.4.1, *see also* 4.1.5 and Section 2. Material thicknesses greater than those shown in Table 2.4.1 may be specially considered by LR, e.g., legs of self-elevating units.

4.1.2 Special consideration will be given to the use of higher tensile steel grades with a minimum yield stress greater than 390 N/mm^2, e.g., legs of self-elevating units.

4.1.3 Material where the principal loads or welding stresses are perpendicular to the plate thickness should have suitable through-thickness properties. The application of through-thickness property Z25 or Z35 grade material is required where tensile stresses exceed 50 per cent of the Rule permissible stress, with plate thickness in excess of 15 mm. In general, Z25 grade would be required; however, for critical joints, Z35 will be required. For certain critical joints with a restricted load path this criterion would be subject to special consideration, for example, mooring fairlead attachments and anchor line or hawser connections.

4.1.4 Steel grades for units required to operate in severe ice conditions will be specially considered. Temperature gradient calculations may be required to assess the design temperature of the structure, *see also* Pt 3, Ch 6.

4.1.5 Minor structural components such as guard rails, walkways and ladders, etc., are, in general, to be constructed of Grade A steel, unless agreed otherwise by LR, *see also* 4.1.4.

4.1.6 For components listed in Table 2.4.2, special consideration may be given to material grades with other impact properties than those required by Table 2.4.1. In such cases, written agreement is required prior to manufacture. This evaluation is to be based on critical engineering assessment involving fracture mechanics testing on welded material from the intended supplier and proposals are to be submitted which include full details of the application, minimum temperature, design, design stresses, fatigue loads and cycles, welding procedures that will be applied and inspection procedures.

Table 2.4.1 Thickness limitations for hull structural steels for various application categories and design temperatures for use in welded construction

Structural category	Required steel grade	Maximum thickness permitted (mm) for various minimum design temperatures, *see* Note 8			
		0°C	–10°C	–20°C	–30°C
Secondary	A	30	20	12,5	X
	B	60	50	25	10
	D	100	100	80	50
	E	150	150	120	100
	AH	50	40	25	10
	DH	100	100	70	50
	EH	150	150	100	80
	FH	150	150	150	120
	AQ	50	40	25	10
	DQ	100	100	70	50
	EQ	150	150	120	80
	FQ	150	150	150	120
Primary	A	20	12,5	X	X
	B	25	25	12,5	X
	D	50	50	30	20
	E	100	100	65	40
	AH	25	25	12,5	X
	DH	50	50	30	20
	EH	120	100	65	40
	FH	150	150	150	100
	AQ	25	25	X	X
	DQ	50	50	30	20
	EQ	120	100	65	40
	FQ	150	150	150	100
Special	A	12.5	X	X	X
	B	15	12,5	X	X
	D	30	30	20	10
	E	100	75	35	30
	AH	20	12,5	X	X
	DH	30	30	12,5	10
	EH	100	75	35	25
	FH	150	100	80	50
	AQ	15	12,5	X	X
	DQ	30	30	12,5	10
	EQ	100	75	30	25
	FQ	150	100	80	60

NOTES
1. X indicates that the material is not permitted for that design temperature and structural category.
2. Materials are to comply with the requirements of Chapter 3 of the Rules for Materials.
3. Q grades refer to quenched and tempered grades (Ch 3,10 of the Rules for Materials).
4. The thicknesses refer to as constructed thicknesses (e.g., design thickness plus any allowances such as corrosion allowance).
5. Requirements for minimum design temperature lower than –30°C will require special consideration which may include the use of fracture mechanics assessments.
6. Thicknesses greater than those shown in this Table may be used subject to special consideration by LR and may include fracture mechanics assessment.
7. The interpolation of thicknesses for intermediate temperatures may be considered.
8. For LNG installations where the minimum hull shell plating temperature used in the design is the result of heat conduction from the cargo rather than environmental conditions, the material thicknesses shall be in accordance with Table 6.5 in Pt 11, Ch 6.

Table 2.4.2 Applications where fracture mechanics may be considered to permit alternative grades of steel

Application
Lattice type leg structures
Cylindrical legs
Footing and mats

■ *Section 1* General

1.1 Application

1.1.1 This Chapter indicates the general design concepts and loading and the general principles adopted in applying the Rule structural requirements given in this Part.

1.1.2 General definitions of span point, derivation of geometric properties of section and associated effective area of attached plating are given in this Chapter.

1.1.3 Additional requirements relating to functional unit types are also dealt with under the relevant unit type given in Part 3.

1.1.4 General principles of subdivision and requirements for cofferdams are given in this Chapter.

1.1.5 Sections 2 and 5 are not applicable to ship units and other surface type units. Instead, structural idealisation aspects of ship units are to comply with Pt 10, Ch 1,8 and Section 3, as applicable. Structural idealisation aspects of other surface type units are to comply with Pt 3, Ch 3,3 of the Rules for Ships.

1.1.6 The number and arrangement of bulkheads on ship units and other surface type units are given in Pt 3, Ch 3,4 of the Rules for Ships, which are to be complied with, as applicable.

1.1.7 For all unit types, structural design loads as given in Section 4 should be considered as applicable.

■ *Section 2* Design concepts

2.1 Elastic method of design

2.1.1 In general, the approval of the primary structure of the unit will be based on the elastic method of design and the permissible stresses in the structure are to be based on the minimum factors of safety defined in Chapter 5. When specifically requested, LR will consider other design methods.

2.2 Limit state method of design

2.2.1 When the limit state method of design is proposed for the structure, the design methods, load combinations and partial factors are to be agreed with LR.

2.3 Plastic method of design

2.3.1 When the plastic method of design based on the ultimate strength is proposed for the structure, the load factors are to be in accordance with an acceptable Code of Practice, *see* Pt 3, Appendix A.

2.4 Fatigue design

2.4.1 All units are to be capable of withstanding the fatigue loading to which they are subjected. The fatigue design requirements are given in Ch 5,5.

■ *Section 3* Structural idealisation

3.1 General

3.1.1 In general, the primary structure of a unit is to be analysed by a three-dimensional finite plate element method. Only if it can be demonstrated that other methods are adequate will they be considered.

3.1.2 The complexity of the mathematical model together with the associated computer element types used must be sufficiently representative of all the parts of the primary structure to enable accurate internal stress distributions to be obtained.

3.1.3 When requested, LR can perform an independent structural analysis of the unit.

3.1.4 For derivation of local scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

3.1.5 Apart from local requirement for web thickness or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.2 Geometric properties of section

3.2.1 The symbols used in this sub-Section are defined as follows:

b = actual width, in metres, of the load-bearing plating, i.e., one-half of the sum of spacings between parallel adjacent members or equivalent supports

f = $0{,}3 \left(l \right)^{2/3}$ but is not to exceed 1,0. Values of this factor are given in Table 3.3.1

l = overall length, in metres, of the primary support member, *see* Fig. 3.3.3

t_p = thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

Table 3.3.1 Effective width factor

l	f	l	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6 and above	1,00

NOTE
Intermediate values to be obtained by linear interpolation.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness t_p mm and of width 600 mm or $40t_p$ mm, whichever is the greater. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing p is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$Z = \frac{d_w}{6000} (3b\, t_p + c\, t_w) \text{ cm}^3$$

where

d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 3.3.1. The value of b is to be taken not greater than:

$50t_p \sqrt{k}$ for welded corrugations

$60t_p \sqrt{k}$ for cold formed corrugations

The value of θ is to be taken not less than 40°. The moment of inertia is to be calculated from:

$$I = \frac{Z}{10} \left(\frac{d_w}{2} \right) \text{ cm}^4$$

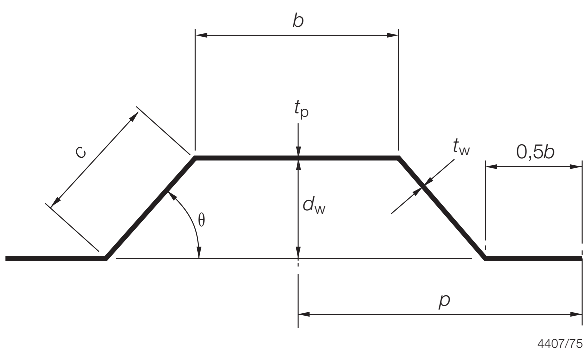


Fig. 3.3.1 Corrugation geometry

3.2.5 The section modulus of a double plate bulkhead over a spacing b may be calculated as:

$$z = \frac{d_w}{6000} (6f\, b\, t_p + d_w\, t_w) \text{ cm}^3$$

where

d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 3.3.2.

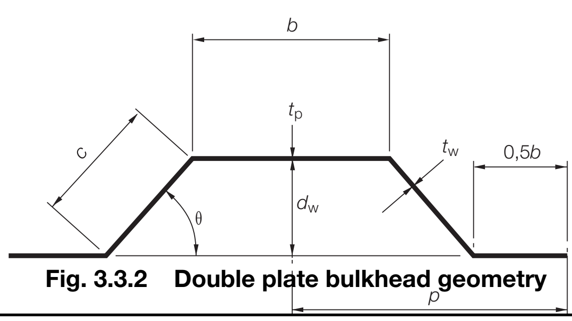


Fig. 3.3.2 Double plate bulkhead geometry

3.2.6 The effective section modulus of a built section may be taken as:

$$z = \frac{a d_w}{10} + \frac{t_w d_w^2}{6000}\left(1 + \frac{200(A - a)}{200A + t_w d_w}\right) \text{ cm}^3$$

where

a = area of the face plate of the member, in cm^2
d_w = depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken
t_w = thickness of the web of the section, in mm
A = area, in cm^2, of the attached plating, *see* 3.2.7. If the calculated value of A is less than the face area a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e., girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:

$A = 10 f\, b\, t_p$ cm^2

(b) For a member attached to corrugated plating and parallel to the corrugations:

$A = 10 b\, t_p$ cm^2

See Fig. 3.3.1.

(c) For a member attached to corrugated plating and at right angles to the corrugations, A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built secondary stiffening members, the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs. For double skin construction the span may be reduced by the depth of primary member web stiffener, *see* Fig. 3.3.3.

(b) For primary support members: the span point is to be taken at a point distant b_e from the end of the member, where

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

See also Fig. 3.3.3.

3.3.2 Where the end connections of longitudinals are designed with brackets to achieve compliance with the *ShipRight FDA Procedure*, no reduction in span is permitted for such brackets unless the fatigue life is subsequently reassessed and shown to be adequate for the resulting reduced scantlings.

3.3.3 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

3.3.4 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

3.4 Grouped stiffeners

3.4.1 Where stiffeners are equally spaced and are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of:

(a) the mean value of the section modulus required for individual stiffeners within the group; and
(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

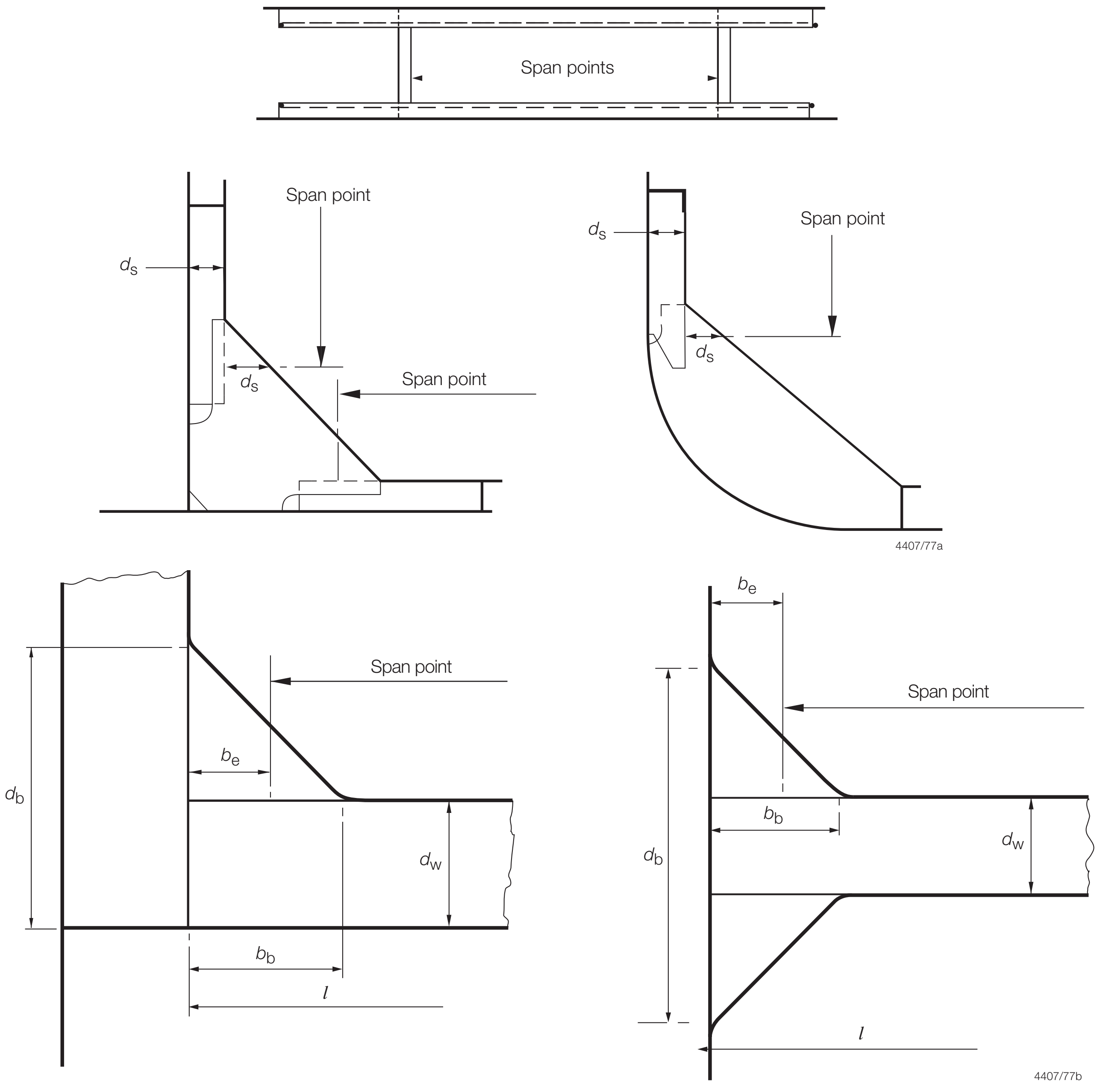


Fig. 3.3.3 Span points

■ *Section 4* Structural design loads

4.1 General

4.1.1 The requirements in this Section define the loads and load combinations to be considered in the overall strength analysis of the unit and the design pressure heads to be used in the Rules for local scantlings.

4.1.2 A unit's modes of operation are to be investigated using realistic loading conditions, including buoyancy, gravity and functional loadings together with relevant environmental loadings. Due account is to be taken of the effects of wind, waves, currents, motions (inertia), moorings, ice, and, where necessary, the effects of earthquake, sea bed-supporting capabilities, temperature, fouling, etc. Where applicable, the design loadings indicated herein are to be adhered to for all types of offshore units.

4.1.3 The Owner/designer is to specify the modes of operation and the environmental conditions for which the unit is to be approved, *see also* Pt 1, Ch 2,2.

4.1.4 The design environmental criteria determining the loads on the unit and its individual elements are to be based upon appropriate statistical information and have a return period (period of recurrence) for the most severe anticipated environment of at least:

(a) 50 years for Mobile Offshore Units.
(b) 100 years for Floating Offshore Installations at a Fixed Location.

If a unit is restricted to seasonal operations in order to avoid extremes of wind and wave, such seasonal limitations must also be specified.

4.1.5 Model tests are to be carried out as necessary and the tests are to include means of establishing the effects of green water loading and/or slamming on the structure through video recordings of the model testing and by measurement of the following:

- Relative motions.
- Forces on local panels mounted at various locations on exposed areas including bow areas of ship units and other surface type units and accommodation areas, *see also* Part 10 for ship units and Chapter 4 and Pt 3, Ch 10,5 for other unit types.

4.1.6 When carrying out model tests, account is to be taken of the following:

- The test programme and the model test facilities are to be to LR's satisfaction.
- The relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined.
- The tests are to be of sufficient duration to establish low frequency motion behaviour.

4.1.7 The unit's limiting design criteria are to be included in the Operations Manual, *see* Pt 3, Ch 1,3.

4.2 Definitions

4.2.1 **Still water condition** is defined as an ideal condition when no environmental loads are imposed on the structure, e.g., no wind, wave or current, etc.

4.2.2 **Gravity and functional loads** are loads which exist due to the unit's weight, use and treatment in still water conditions for each design case. All external forces which are responses to functional loads are to be regarded as functional loads, e.g., support reactions and still water buoyancy forces.

4.2.3 **Environmental loads** are loads which are due directly or indirectly to environmental actions. All external forces which are responses to environmental loads are to be regarded as environmental loads, e.g., mooring forces and inertia forces.

4.2.4 **Accidental loads** are loads which occur as a direct result of an accident or exceptional circumstances, e.g., loads due to collisions, dropped objects and explosions, etc. *See also* 4.16.

4.3 Load combinations

4.3.1 The structure is to be designed for the most unfavourable of the following combined loading conditions (as relevant to the unit):

(a) Maximum gravity and functional loads.
(b) Design environmental loads and associated gravity and functional loads.
(c) Accidental loads and associated gravity and functional loads.
(d) Environmental loads and associated gravity and functional loads after credible failures or accidents, *see* Pt 4, Ch 4,1.3.5 for redundancy assessment of column-stabilised units and Pt 10, Ch 2,3.4.1 for assessment of ship units in the flooded condition.

Note

Load combination (c) relates to the loading and condition of the unit at the time of the accidental event. Load combination (d) relates to the loading and condition of the unit following the accidental event and allowing for agreed documented mitigation measures to be put in place. *See also* 4.16, Chapter 4 and Part 10 for applicability to unit types.

4.3.2 Special requirements applicable to column-stabilised and self-elevating units are also defined in Chapter 4.

4.3.3 Permissible stresses relevant to the combined loading conditions are given in Chapter 5.

4.4 Gravity and functional loads

4.4.1 All gravity loads, including static loads such as weight, outfit, stores, machinery, ballast, etc., and live functional loads from operating derricks, cranes, winches and other equipment are to be considered. All practical combinations of gravity and functional loads are to be included in the design cases.

4.5 Buoyancy loads

4.5.1 Buoyancy loads on all underwater parts of the structure, taking account of heel and trim when appropriate, are to be considered.

4.6 Wind loads

4.6.1 Account is to be taken of the wind forces acting on that part of the unit which is above the still water level in all operating conditions and of the following:

(a) Consideration is to be given to wind gust velocities which are of brief duration and sustained wind velocities which act over intervals of time equal to or greater than one minute, including squalls where relevant. Different wind velocity averaging time intervals applicable to different structural categories to be used in design calculations are shown in Table 3.4.1.
(b) Wind velocities are to be specified relative to a standard reference height of 10 m above still water level for each operating condition.

(c) The variation of wind velocity with height for each operating condition may be determined from the following expression:

$$V_H = V_R \left(\frac{H}{H_R}\right)^n$$

where

V_H = wind velocity at specified height, in m/s
V_R = wind velocity at specified reference height H_R, in m/s
H = specified height above sea level, in metres
H_R = reference height, in metres
n = power law exponent
for 3 second gust n = 0,077
for 5 second mean n = 0,08
for 15 second mean n = 0,09
for 1 minute mean n = 0,125
for 10 minute mean n = 0,13.

Table 3.4.1 Structural parts to be considered for wind loading

Wind speed averaging time interval	Structural category
3 second gust	Individual members and equipment secured to them
5 second mean (sustained)	Part or whole of a structure whose greatest horizontal or vertical dimension does not exceed 50 m
15 second mean (sustained)	Part or whole of a structure whose greatest horizontal or vertical dimension exceeds 50 m
1 minute mean (sustained) *see* Note	The whole structure of the unit regardless of dimension for use with the maximum wave and current loads

NOTE
In no case is the one minute mean value to be taken less than 25,8 m/s.

4.6.2 The wind force is to be calculated for each part of the structure and is not to be taken less than:

$$F = K_w A V^2 C_s \quad \text{N (kgf)}$$

where

F = net force acting on any member or part of the unit. This includes the effect of any suction on back surfaces
K_w = 0,613 (0,0625)
A = projected area of all exposed surfaces in upright or heeled position, in m^2
V = wind velocity, in m/s, *see* 4.6.1
C_s = shape coefficient as given in Table 3.4.2.

Table 3.4.2 Values of coefficient C_s

Shape	C_s
Spherical	0,40
Cylindrical	0,50
Large flat surface (hull, deckhouse, smooth underdeck areas)	1,00
Drilling derrick	1,25
Wires	1,20
Exposed beams and girders under deck	1,30
Small parts	1,40
Isolated shapes (cranes, booms, etc.)	1,50
Clustered deckhouses or similar structures	1,10

NOTE
Shapes or combinations of shapes which do not readily fall into the specified categories will be subject to special consideration.

4.6.3 When calculating wind forces the following procedures should be considered:

(a) Shielding may be taken into account when a member or structure lies closely enough behind another to have a significant effect. Procedures for determining the shielding effect and loading are to be acceptable to LR.
(b) Areas exposed due to heel, such as underdecks, etc., are to be included using the appropriate shape coefficients.
(c) If several deckhouses or structural members, etc., are located close together in a plane normal to the wind direction, the solidification effect is to be taken into account. The shape coefficient may be assumed to be 1,1.
(d) Isolated houses, structural shapes, cranes, etc., are to be calculated individually, using the appropriate shape coefficient.
(e) Open truss work commonly used for derrick towers, booms and certain types of masts may be approximated by taking 30 per cent of the projected block area of each side, e.g., 60 per cent of the projected block area of one side for double-sided truss work. An appropriate shape coefficient is to be taken from Table 3.4.2.

4.6.4 For slender structures and components, the effects of wind-induced cross-flow vortex vibrations are to be included in the design loading.

4.6.5 For slender structures sensitive to dynamic loads, the static gust wind force is to be multiplied by an appropriate dynamic amplification factor.

4.7 Current loads

4.7.1 In storm conditions, the current has two main components: the tidal and wind driven components. Submitted information on currents is to include tidal and wind induced components and the variation of their profiles with water depth, *see* 4.9.6 and 4.9.7. In addition, the effects of general circulation and loop currents are to be included where appropriate.

4.8 Orientation and wave direction

4.8.1 Loadings are to be assessed using sufficient wave headings and crest positions to determine the most severe loading on the unit. In addition to the design wave height and period, the unit is to be designed to withstand shorter period waves of less height when these can induce more severe loading on parts or the whole unit due to dynamic effects, etc.

4.8.2 Where a unit is required to operate at locations exposed to wind waves and swell waves acting simultaneously then this is to be taken into account when determining the wave loads.

4.9 Wave loads

4.9.1 Design wave criteria specified by the Owner/designer may be described either by means of design wave energy spectra or deterministic design waves having appropriate shape, size and period. The following should be taken into account:

(a) The maximum design wave heights specified for each operating condition should be used to determine the maximum loads on the structure and principal elements. Consideration is to be given to waves of less than maximum height, where due to their period, the effects on various structural elements may be greater.
(b) Wave lengths are to be selected as the most critical ones for the response of the structure or element to be investigated.
(c) An estimate is to be made of the probable wave encounters that the unit is likely to experience during its service life in order to assess fatigue effects on its structural elements.
(d) When units are to operate in intermediate or shallow water, the effect of the water depth on wave heights and periods and of refraction due to sea bed topography is to be taken into account.

4.9.2 The forces produced by the action of waves on the unit are to be taken into account in the structural design, with regard to forces produced directly on the immersed elements of the unit and forces resulting from heeled positions or accelerations due to its motion. Theories used for the calculation of wave forces and selection of relevant coefficients are to be acceptable to LR.

4.9.3 The wave forces may be assessed from tests on a representative model of the unit by a recognised laboratory, *see* 4.1.5 and 4.1.6.

4.9.4 Wave theories used for the calculation of water particle motions are to be acceptable to LR and when using acceptable wave theories for wave force determination, reliable values of C_D and C_M which have been obtained experimentally for use in conjunction with the specific wave theory are to be used. Otherwise published data are to be used.

4.9.5 Consideration is to be given to the possibility of wave impact and wave induced vibration in the structure.

4.9.6 Where sea current acts simultaneously with waves, the effect of the current is to be included in the load estimation. In those cases this superposition is deemed necessary, the current velocity should be added vectorially to the wave particle velocity. The resultant velocity is to be used to compute the total force.

4.9.7 The following methods may be used for load estimation:

(a) The forces on structural elements with dimensions less than 0,2 of the wave length subject to drag/inertia loading due to wave and current motions can be calculated from the Morison's equation:

$F = 0{,}5 C_D \rho A u |u| + C_M \rho V a$

where

F = force per unit length of member
C_D = drag coefficient
ρ = density of water
A = projected area of member per unit length
u = component of the water particle velocity at the axis of the member and normal to it (calculated as if the member were not there)
$|u|$ = modulus of u
C_M = inertia coefficient
V = volume of water per unit length
a = component of the water particle acceleration at the axis of the member and normal to it (calculated as if the member were not there)

(b) Overall loading on an offshore structure is determined from the summation of loads on individual members at a particular time. The proper values of C_D and C_M for individual members to use with Morison's equation will depend on a number of variables, for example: Reynolds number, Keulegan-Carpenter number, inclination of the member to local flow and effective roughness of marine growth. Therefore, fixed values for all conditions cannot be given. Typical values for circular cylindrical members, will range from 0,6 to 1,4 for C_D and 1,3 to 2,0 for C_M. The values selected are not to be smaller than the lower limits of these ranges. For inclined members, the drag forces in Morison's equation are to be calculated using the normal component of the resultant velocity vector.
(c) General values of hydrodynamic coefficients may be used in the Morison's equation for the calculation of overall loading on the structure, namely:
    - For circular cylinders covered by hard marine growth, C_D is to be not less than 0,7.
    - For circular cylinders not covered by hard marine growth, C_D is to be not less than 0,6.
    - For circular cylinders, C_M is to be not less than 1,7.

    If joint probability predictions of wave and current are included in the design procedure or if the conservatism is reduced in any part, consideration is to be given to increasing the drag coefficient associated with marine growth.
(d) Diffraction theory is normally appropriate to determine wave loads where the member is large enough to modify the flow field.

4.9.8 Account is to be taken of the increase of overall size and roughness of submerged members due to marine growth when calculating loads due to wave and current, *see* 4.13.

4.10 Inertia loads

4.10.1 Dynamic loads imposed on the structure by accelerations due to the unit's motion in a seaway are to be included in the structural design calculations. The dynamic loads may be obtained from model test results or by calculation. The methods of calculation are to be acceptable to LR.

4.11 Mooring loads

4.11.1 Mooring loads are to be considered for units operating afloat with positional mooring systems, *see* Pt 3, Ch 10. The following are to be considered:

- The overall strength of the structure.
- The local strength where the mooring line forces are transmitted to the hull.

4.11.2 The support structure in way of mooring equipment is to be designed for the minimum design breaking load of the mooring line, determined in accordance with Pt 3, Ch 10. *See also* Ch 6,1.

4.12 Snow and ice loads

4.12.1 Consideration is to be given to the extent to which snow and ice may accumulate on the exposed structure under any particular weather conditions. The wind resistance of exposed structural elements will be increased by the growth of ice. Details of the thickness and distribution of accumulation are to be established and taken into account in the design, *see also* Pt 3, Ch 6.

4.12.2 The increased loading caused by the accumulation of snow and ice on any part of the structure is to be taken into account.

4.12.3 Values for the thickness, density and variation with height of accumulated snow and ice are to be derived from meteorological data acceptable to LR.

4.12.4 The overall distribution of snow and/or ice on topside structure is to be taken as a thickness t_i on the upper and windward faces of the deck structures or members under consideration, where t_i is the basic thickness obtained from the meteorological data. The distribution of ice on individual members may be assumed to be as shown in Fig. 3.4.1.

4.12.5 It may be assumed that there is no increase of drag coefficient in the presence of ice.

4.12.6 The appropriate combinations of snow and ice loadings with other design environmental loads are to be specially considered and agreed with LR. In general, extreme snow and ice loads are to be combined with other environmental loads corresponding to the design five-year return criteria for the unit.

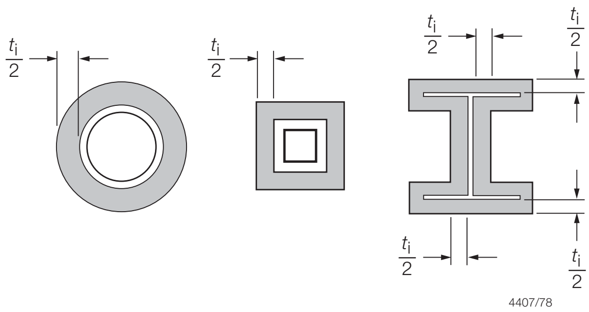


Fig. 3.4.1
Assumed distribution of ice on individual members for calculation purposes

4.13 Marine growth

4.13.1 Marine growth will increase the weight and the overall dimensions of submerged members and alter their surface characteristics. These effects will increase the loads applied to the structure. The thickness of marine growth taken into account in the design is to be stated in the Operations Manual and the design limit is not to be exceeded in service.

4.14 Hydrostatic pressures

4.14.1 The hydrostatic pressure head to be used as the basis for the design of internal spaces is to be the greatest of the following:

(a) For tanks, the maximum head during normal operation.
(b) For shell boundaries, the hydrostatic head due to external sea pressure. For semi-submersible units this is not to be taken as less than 6m.
(c) For watertight boundaries, the head measured to the worst damage waterline, *see* Chapter 7.

The minimum design pressure heads for local strength are to be in accordance with Chapter 6.

4.14.2 Where testing the tank involves pressure heads in excess of those derived in 4.14.1, the excess may be taken into account by the use of a load factor applied to the design head. Where this is done, it is to be clearly stated in the calculations.

4.15 Deck loads

4.15.1 The maximum design uniform and concentrated deck loads for all areas of the unit in each mode of operation are to be taken into account in the design. The minimum design deck loads for local strength are to be in accordance with Chapter 6.

4.16 Accidental loads

4.16.1 The following credible failures and accidents are to be considered in the design as applicable to the function of the unit:
- Collision.
- Dropped object.
- Blast.
- Accidental flooding.
- Loss of primary bracing (column-stabilised unit).
- Emergency helicopter landings.

4.16.2 Collision loads imposed by attending vessels which may be approaching, mooring or lying alongside the unit are to be considered in the design. The unit is to be designed to withstand accidental impacts between attending vessels and the unit and be capable of absorbing the impact energy.

4.16.3 The kinetic energy to be considered is normally not to be less than:
- 14 MJ for sideway collision;
- 11 MJ for bow or stern collision;

corresponding to an attending vessel of 5000 tonnes displacement with impact velocity 2 m/s.

4.16.4 A reduced impact energy may be accepted upon special consideration, taking into account the environmental design criteria.

4.16.5 The energy absorbed by the unit during a collision impact will be less than or equal to the total impact kinetic energy, depending on the relative stiffnesses of the relevant parts of the unit and the impacting ship/unit and also on the mode of collision and ship/unit operation. These factors may be taken into account when considering the energy absorbed by the unit, *see also* Ch 4,1 and Ch 4,3 for column-stabilised and self-elevating units respectively.

4.16.6 Collision is to be considered for all elements of the unit which may be hit by sideway, bow or stern collision. The vertical extent of the collision zone is to be based on the depth and draught of attending ships/units and the relative motion between the attending ships/units and the unit.

4.16.7 The accidental impact loads caused by dropped objects from cranes are to be considered in the design of the unit when the arrangements of the unit are such that the failure of a vital structure member could result in the collapse of the structure.

4.16.8 Critical areas for dropped objects are to be determined on the basis of the actual movement of crane loads over the unit.

4.16.9 The structural bulkheads protecting accommodation areas, and other structures that may be subject to blast pressures, are to be designed for accidental blast loading, where applicable. The design blast pressures are to be defined by the Owners/designers, *see* Pt 7, Ch 3,2.4.2 and are to comply with National requirements. Blast loads are to be combined with the still water loads. Environmental loads need not be considered. Design calculations are to be submitted which may be based on elastic analysis or elastoplastic design methods, *see also* 4.16.11.

4.16.10 Accidental flooding of a single hull compartment is to be considered in the design of the unit. As a minimum, the compartments to be addressed are to include those set out in Chapter 3 of the 2009 IMO MODU Code as applicable to the unit type. Special consideration will be given to unit types not addressed by the 2009 IMO MODU Code.

4.16.11 Units with slender members where the failure of a single member could result in the overall collapse of the unit's structure are to be considered for credible failure of such members, *see* Chapter 4.

4.16.12 Requirements for helicopter landing areas are given in Ch 6,5.

4.16.13 Permissible stresses for accidental load conditions are given in Ch 5,2.

4.16.14 When a National Administration in the country in which the unit is registered and/or in which it is to operate has additional requirements for accidental loads these are to be taken into account in the design loadings.

4.17 Fatigue design

4.17.1 Fatigue damage due to cyclic loading must be considered in the design of all unit types.

4.17.2 Fatigue design calculations are to be carried out in accordance with the analysis procedures and general principles given in Ch 5,5 or other acceptable method.

4.17.3 The factors of safety on calculated fatigue life are to comply with Ch 5,5. Additional factors of safety are given in Pt 10, Ch 1,19 for ship units.

4.18 Other loads

4.18.1 If attending ships/units are to be moored to the unit, the forces imposed by the moorings on the structure are to be taken into account in the design.

4.18.2 Other local loads imposed on the structure by equipment and mooring and towing systems are to be considered in the design of the structure.

4.18.3 When partial filling of tanks is contemplated in operating conditions, the risk of significant loads due to sloshing induced by any of the vessel motions is to be considered. An initial assessment is to be made to determine whether or not a higher level of sloshing investigation is required, using the procedure given in Pt 3, Ch 3,5 of the Rules for Ships.

Section 5
Number and disposition of bulkheads

5.1 General

5.1.1 The number and disposition of watertight bulkheads are to be arranged to ensure adequate strength and the arrangements are to suit the requirements for subdivision, floodability and damage stability. They are also to be in accordance with the requirements of the National Administration in the country in which the unit is registered and/or in which it is to operate, *see* Pt 1, Ch 2,1 and Chapter 7.

5.1.2 Bulkheads are to be spaced at reasonable uniform intervals. Where, due to the design of a unit, the spacing of bulkheads is unusually great, the transverse strength of the unit is to be maintained by fitting suitable web frames between the bulkheads. Details of bulkheads and intermediate web frames are to be submitted for approval.

5.1.3 The requirements of 5.3.3 are to be complied with as applicable.

5.2 Self-elevating units

5.2.1 The arrangement of longitudinal and transverse bulkheads are to satisfy the overall strength requirements given in Chapters 4 and 5 when the unit is in the elevated position and when afloat.

5.2.2 The number and arrangement of watertight bulkheads are to meet the requirements of damage stability.

5.2.3 Watertight bulkheads are to extend to the uppermost continuous deck.

5.3 Column-stabilised units

5.3.1 The arrangement of watertight bulkheads and flats are to be made effective to that point necessary to meet the requirements of damage stability.

5.3.2 The arrangement of longitudinal and transverse bulkheads in the upper and lower hulls and in columns are to satisfy the overall strength requirements given in Chapters 4 and 5.

5.3.3 The subdivision and arrangement of bulkheads and cofferdams on production and oil storage units are also to comply with Pt 3, Ch 3.

5.4 Buoys and deep draught caissons

5.4.1 The number and arrangement of structural bulkheads are to satisfy the overall strength requirements in Chapter 5. The requirements of 5.1.1 and 5.3.3 are to be complied with.

5.5 Tension-leg units

5.5.1 In general, the number and arrangement of structural bulkheads are to comply with 5.3.

5.6 Protection of tanks carrying oil fuel and lubricating oil

5.6.1 The requirements for the protection of tanks carrying oil fuel and lubricating oil, which are given in Pt 3, Ch 3,4.7 of the Rules for Ships, are to be complied with, as applicable.

Section

■ *Section 1* Column-stabilised units

1.1 General

1.1.1 This Section outlines the structural design requirements of column-stabilised (semi-submersible) units as defined in Pt 1, Ch 2,2. Additional requirements for particular unit types related to the design function of the unit are given in Part 3.

1.1.2 Units which are required to operate while resting on the sea bed are also to comply with the requirements of Section 2.

1.1.3 Production and oil storage units are to comply with the requirements of Pt 3, Ch 3. Columns and pontoons designed for the storage of oil in bulk storage tanks are to be of double hull construction. If pontoon oil storage tanks are always kept empty in transit conditions, a double bottom need not be fitted, except where a double bottom is required by a National Administration and/or Coastal State Authority.

1.1.4 If it is intended to dry-dock the unit, the bottom structure is to be suitably strengthened to withstand the loadings involved. The proposed docking arrangement plan and maximum bearing pressures are to be submitted.

1.2 Air gap

1.2.1 In all floating modes of operation, column-stabilised units are normally to be designed to have a clearance 'air gap' between the underside of the upper hull deck structure and the highest predicted design wave crest. Reasonable clearance is to be maintained at all times, taking into account the predicted motion of the unit relative to the surface of the sea. Calculations, model test results or prototype reports are to be submitted for consideration.

1.2.2 In cases where the unit is designed without a clearance air gap, the scantlings of the upper hull deck structure are to be designed for wave impact forces, *see also* 1.4.4.

1.3 Structural design

1.3.1 The general requirements for structural design are given in Chapter 3, but the additional requirements of this Section are to be complied with.

1.3.2 The structure is to be designed to withstand the static and dynamic loads imposed on the unit in transit and semi-submerged conditions. All relevant loads as defined in Chapter 3 are to be considered and the permissible stresses due to the overall and local load effects are to be in accordance with Chapter 5. The minimum local scantlings of the unit are to comply with Chapter 6.

1.3.3 All modes of operation are to be investigated and the relevant design load combinations defined in Ch 5,1.2 are to be complied with. The loading conditions applicable to a column-stabilised unit are shown in Table 4.1.1.

Table 4.1.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 2	(d) *See* Note 2
Operating	✓	✓	✓	✓
Survival	✓	✓	✓	✓
Transit	✓	✓	✓	✓

NOTES
1. For definition of loading conditions (a) to (d), *see* Ch 3,4.3.
2. For loading conditions (c) and (d) as applicable to a column-stabilised unit, *see* 1.3.5 to 1.3.7.

1.3.4 The overall strength of the unit is to be analysed by a three-dimensional finite element method in accordance with Ch 3,3.

1.3.5 In order to ensure adequate structural redundancy after credible failure or accidents, the structure is to be investigated for loading condition (d) in Table 4.1.1. The environmental loads for this load case are to be taken as the same as determined for loading condition (b). The structure is to be able to withstand the following failures without causing the overall collapse of the unit's structure:
- The failure of any main primary bracing member.
- When the upper hull structure consists of heavy or box girder construction, the failure of any primary slender member.

1.3.6 The general requirements for investigating accidental loads are defined in Ch 3,4.16, but in the case of a column-stabilised unit, collision loads against a column or pontoon will normally only cause local damage to the structure and consequently loading condition (c) in Table 4.1.1 need not be investigated from the overall strength aspects. The requirements for very slender columns will be specially considered.

1.3.7 The permissible stress levels after credible failures or accidents are to be in accordance with Chapter 5.

1.4 Upper hull structure

1.4.1 Decks and supporting grillage structures forming part of the primary structure are to be designed to resist both the overall and local loadings.

1.4.2 Openings in primary bulkheads and decks are normally to be represented in the structural model. Bulkhead openings in 'tween decks are not, in general, to be fitted in the same vertical line. When large bulkhead openings are cut in the structure which were not included in the structural model, the bulkhead thickness is to be increased in way of the opening to compensate for the loss of shear area and stiffness.

1.4.3 When the primary deck structure consists of heavy or box girder construction and the infill deck plating is considered to be secondary structure, only the main deck girders and the secondary deck plating stiffeners need satisfy the buckling strength requirements given in Chapter 5. The infill deck plating thickness and its contribution to the overall strength of the structure will be specially considered, *see also* Ch 6,4.

1.4.4 When the upper hull structure is designed to be waterborne for operational purposes the upper hull scantlings are not to be less than those specified for shell boundaries of self-elevating units as defined in Ch 6,3.

1.4.5 Columns should be aligned and integrated with the bulkheads in the upper hull structure. Particular attention should be given to the detail design at the intersection of columns with the upper hull structure to minimise stress concentrations.

1.5 Columns

1.5.1 Columns are to be designed to withstand the forces and moments resulting from the overall loadings, together with forces and moments due to wave loadings and internal tank pressures.

1.5.2 In general, internal spaces within the columns are to be designed for the pressure heads defined in Ch 3,4.14.

1.5.3 High local loads are also to be taken into account in the overall design strength of the columns.

1.5.4 Internal column structure supporting main bracings is in general not to be of a lesser strength than the bracing itself.

1.5.5 When bracing forces are designed to be transmitted to the column shell, the resulting column shell stresses are to be combined with the stresses due to the hydrostatic pressure and overall forces.

1.6 Lower hulls

1.6.1 Lower hulls or pontoons are to be designed for overall bending, shear forces, and axial forces due to end pressure when combined with the local hydrostatic pressure as defined in Ch 3,4.14.

1.6.2 Irrespective of the tank loading arrangement, the scantlings of tanks are to be verified in both full and empty conditions.

1.6.3 Columns are, as far as practicable, to be continuous through the plating of the lower hull deck structure and be aligned and integrated with the internal bulkheads and/or side shell.

1.6.4 Where the column shell plating is intercostal with the lower hull deck, the deck plating below the columns is to be suitably increased and is to have steel grades with suitable through-thickness properties, *see* Ch 2,4.1.3.

1.6.5 Particular attention should be given to the design of the local structure at the intersection of columns with lower hulls and due account should be given to penetrations and stress concentrations.

1.7 Main primary bracings

1.7.1 Bracing members are to be designed to withstand the stresses imposed by the overall loading, together with local stresses due to wave, current and buoyancy forces and, when applicable, hydrostatic pressure.

1.7.2 Bracings are in general to be made watertight and provided with adequate means of access to enable internal inspection to be carried out when the unit is afloat.

1.7.3 Watertight bracings are to be designed for the hydrostatic pressure loads defined in Ch 3,4.14, and the scantlings are to be verified against buckling due to combined axial stresses and hoop stresses caused by external hydrostatic pressure. Ring stiffeners are to be fitted where necessary.

1.7.4 Attachments and penetrations to the shell of bracings are to be avoided as far as practicable. If attachments are unavoidable they are generally to be welded to suitable doubler plates having well rounded corners. Special consideration will be given to alternative proposals. In all cases the attachment is to be designed to minimise the resulting stress concentration in the brace and the fatigue life is to be checked.

1.7.5 Leak detection and drainage arrangements of watertight bracings are to be in accordance with Pt 5, Ch 13,3.

1.7.6 The scantlings and arrangements of free-flooding bracings will be specially considered.

1.8 Bracing joints

1.8.1 Joints at the intersection of bracings or between bracings and columns are to be designed to transmit the bending, direct and shear forces involved in such a manner as to reduce, so far as possible, the risk of fatigue failure. Stress concentrations are to be minimised by good detail design and, in general, nominal stress levels are to be made lower than in the adjacent structure by increasing plate thickness or suitably flaring the member ends, or both. Ring stiffeners or other welded attachments across the principal stress direction are to be avoided wherever possible in all regions of high stress. It this is not possible (e.g., where required to support bracket ends on otherwise unstiffened plating), the weld is to have a smooth profile without undercutting. Continuity of strength is to be maintained through the joint, and shear web plates and other axial stiffening members are to be made continuous.

1.8.2 Special attention is also to be given to the qualities of bracing details, e.g., openings, penetrations, stiffener ends, brackets and other attachments. The welding procedure is to be such as to minimise the risk of cracks, lack of penetration and lamellar tearing of the parent steel.

1.8.3 Joints depending upon transmission of tensile stresses through the thickness of the plating of one of the members (which may result in lamellar tearing) are to be avoided wherever possible. Plate steel used in such locations shall have suitable through-thickness properties.

1.9 Lifeboat platforms

1.9.1 The strength of lifeboat platforms is to be verified with the unit in the upright condition and in the inclined condition at an angle corresponding to the worst damage waterline, and at an inclined angle of 15° in any direction.

1.9.2 For calculation purposes, the weight of the lifeboat is to be taken as the weight when fully manned and equipped. The platform weight is to be taken as the steel weight plus the weight of davits and equipment. Symmetrical and unsymmetrical load cases are to be considered as appropriate, e.g., one lifeboat launched and the other lowering. The design calculations are to be submitted for information.

1.9.3 The following dynamic load factors are to be included in the calculations:

Item:	Factor:
Platform weight	0,3 g
Lifeboat weight when stowed	0,3 g
Lifeboat weight when lowering	0,5 g

1.9.4 In the upright condition and in the inclined condition the permissible stresses are to comply with Ch 5,2.1.1, loadcase (a) and (b) respectively.

1.9.5 After installation of the lifeboats, testing is to be carried out to the satisfaction of LR's Surveyors.

1.10 Topside structure

1.10.1 The minimum scantlings of superstructures and deckhouses are to comply with the requirements of Ch 6,9. Bulwarks and guard rails are to comply with Ch 6,10.

1.10.2 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment supporting structures including derricks and flare structures are considered to be classification items, regardless of whether or not the process/drilling plant facility is classed, and the loadings are to be determined in accordance with Pt 3, Ch 8,2. Permissible stress levels are to comply with Chapter 5.

1.10.3 The boundary bulkheads of accommodation spaces which may be subjected to blast loading are to be designed in accordance with Ch 3,4 and permissible stress levels are to satisfy the factors of safety given in Ch 5,2.1.1(c).

1.10.4 Units with a process plant facility which comply with the requirements of Pt 3, Ch 8 will be eligible for the assignment of the special features class notation **PPF**.

1.10.5 Units with a drilling plant facility which comply with the requirements of Pt 3, Ch 7 will be eligible for the assignment of the special features class notation **DRILL**.

■ *Section 2* **Sea bed-stabilised units**

2.1 General

2.1.1 This Section outlines the structural design requirements of sea bed-stabilised units as defined in Pt 1, Ch 2,2. Additional requirements for particular unit types related to the design function of the unit are given in Part 3. Self-elevating units are to comply with Section 3.

2.1.2 Units of this type are generally designed to operate under normal operating environmental conditions and severe storm conditions whilst resting on the sea bed. The design transit condition and design limitations are to be specified by the Owner/designer.

2.1.3 The structural analysis and determination of scantlings is to be on the basis of distribution of loadings and ballast required to satisfy 2.1.2 and all units are to have adequate reserve of bearing pressure on the support footings, pontoons or mats.

2.1.4 The requirements of Sections 1 and 3 are to be complied with as applicable to the design of the unit.

2.1.5 The permissible stress levels in all operating modes are to comply with Chapter 5.

2.1.6 The minimum local scantlings are to comply with the requirements of Chapter 6, for column-stabilised units as applicable, but the bottom structure should not be less than required for tank bulkheads in Chapter 6 using the load head h_4 equivalent to the maximum design bearing pressure. In general, bottom primary members supporting shell stiffeners are to be spaced not more than 1,85 m apart and side girders or equivalent are to be spaced 2,2 m apart. The buckling strength of the primary member webs is to be in accordance with Chapter 5, *see also* 2.4.

2.2 Air gap

2.2.1 For on-bottom modes of operation, the clearance air gap between the underside of the deck structure and the highest predicted design wave crest is to be in accordance with 3.2.1. In transit conditions, the air gap is to be in accordance with 1.2. Calculations, model test results or prototype reports are to be submitted for consideration.

2.3 Operating conditions

2.3.1 Classification will be based upon the Owner's/ designer's assumptions in operating the unit and the sea bed conditions. These assumptions are to be recorded in the Operations Manual. It is the responsibility of the Operator to ensure that actual conditions do not impose more severe loadings on the unit.

2.3.2 Procedures and limitations for ballasting and re-floating the unit in order to avoid overstressing the structure by static or dynamic loads are to be clearly defined in the Operations Manual, *see* Pt 3, Ch 1,3.

2.4 Corrosion protection

2.4.1 The corrosion allowance for wastage and the means of protection are to be to the satisfaction of LR and are to be agreed at the design stage.

2.4.2 The general requirements for corrosion protection are to comply with Part 8.

■ *Section 3* Self-elevating units

3.1 General

3.1.1 This Section outlines the structural design requirements of self-elevating units. Additional requirements for particular unit types related to the design function of the unit are given in Part 3.

3.1.2 A self-elevating unit is a floating unit which is designed to operate as a sea bed-stabilised unit in an elevated mode, *see* Pt 1, Ch 2,2.

3.1.3 Production units are to comply with the requirements of Pt 3, Ch 3 as applicable.

3.1.4 The structural analysis and determination of primary scantlings are to be on the basis of the distribution of loadings expected in all modes of operation.

3.2 Air gap

3.2.1 When in the elevated position, the unit is to be designed to have a clearance air gap between the underside of the hull structure and the highest predicted design wave crest superimposed on the maximum surge height over the maximum mean astronomical tide. The minimum clearance is not to be less than 1,5 m. Calculations, model test results or prototype reports are to be submitted for consideration.

3.3 Structural design

3.3.1 The structure is to be designed to withstand the static and dynamic loads imposed upon it in transit, installation and elevated conditions. All relevant distributions of gravity and variable loads are to be considered, as are stresses due to the overall and local effects, *see* Ch 3,4.

3.3.2 The permissible stresses are to be in accordance with Chapter 5 and the minimum local scantlings of the unit are to comply with Chapter 6.

3.3.3 All modes of operation are to be investigated and the relevant design load combinations defined in Ch 5,1.2 are to be complied with. The loading conditions applicable to a self-elevating unit are shown in Table 4.3.1.

Table 4.3.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 2	(d) *See* Note 2
Site installation and re-floating		✓		
Operating	✓	✓	✓	✓
Survival	✓	✓	✓	✓
Transit	✓	✓	✓	✓

NOTES
1. For definition of loading conditions (a) to (d), *see* Ch 3,4.3.
2. For loading conditions (c) and (d) as applicable to a self-elevating unit, *see* 3.3.4 to 3.3.6.

3.3.4 The general requirements for investigating accidental loads are defined in Ch 3,4.16. In transit conditions, collision loads against the hull structure will normally only cause local damage to the hull structure and consequently loading condition (c) in Table 4.3.1 need not be investigated from the overall strength aspects. When in the elevated position, accidental damage to the legs is to be considered in the design and the unit is to be capable of absorbing the energy of impact in association with environmental loads corresponding to the appropriate one year storm condition.

3.3.5 In general, for loading condition (c) in Table 4.3.1, the level of impact energy absorbed by the local leg structure is not to be taken less than 2 MJ. If the unit is only to operate in protected waters, as defined in Pt 1, Ch 2,2.4, the level of impact energy absorbed by the local leg structure may be reduced but should not be less than 0,5 MJ. Collision loads will, in general, only cause local damage to one leg, but the possibility of progressive collapse and overturning should be considered in the design calculations which should be submitted for consideration.

3.3.6 The permissible stress levels after credible failures or accidents are to be in accordance with Chapter 5.

3.3.7 Fatigue damage due to cyclic loading is to be considered in the design of the legs of the unit for transit and elevated conditions. Fatigue damage is considered accumulative throughout the unit's design life. The extent of the fatigue analysis will be dependent on the mode and area of operations, *see* Ch 5,5.

3.4 Hull structure

3.4.1 The hull is to be considered as a complete structure having sufficient strength to resist all induced stresses while in the elevated position and supported by its legs. All fixed and variable loads are to be distributed, by an accepted method of rational analysis, from the various points of application to the supporting legs. The scantlings of the hull are then to be determined consistent with this load distribution.

3.4.2 Due account must be taken of loadings induced in the transit condition from external sea heads, variable deck loads and legs.

3.5 Deckhouses

3.5.1 Deckhouses are to have sufficient strength for their size, function and location. Requirements for scantlings are given in Ch 6,9.

3.5.2 Special consideration is to be given to the scantlings of deckhouses and deck modules which will not be subjected to wave loading in any operating condition such as units which are 'dry-towed' to the operating location.

3.6 Structure in way of jacking or elevating arrangements

3.6.1 Load carrying members in the jackhouses and frames which transmit loads between the legs and the hull are to be designed for the maximum design loads and are to be so arranged that loads transmitted from the legs are properly diffused into the hull structure. The scantlings of jackhouses are not to be less than required for deckhouses in accordance with Ch 6,9.

3.7 Leg wells

3.7.1 The scantlings and arrangements of the boundaries of leg wells are to be specially considered and the structure is to be suitably reinforced in way of leg guides, taking into account the maximum forces imposed on the structure. The minimum scantlings of leg wells are to comply with Ch 6,3.3.

3.8 Leg design

3.8.1 Legs may be either shell type or lattice type. Independent footings may be fitted to the legs or legs may be permanently attached to a bottom mat. Shell type legs may be designed as either stiffened or unstiffened shells.

3.8.2 Where legs are fitted with independent footings, proper consideration is to be given to the leg penetration of the sea bed and the end fixity of the leg.

3.8.3 Leg scantlings are to be determined in accordance with a method of rational analysis and calculations submitted for consideration, *see* Ch 3,3.

3.8.4 For lattice legs, the slenderness ratio of the main chord members between joints is not to exceed 40, or two thirds of the slenderness ratio of the leg column as a whole, whichever is the lesser, unless it can be shown that a calculation taking into account beam-column effect, joint rigidity and joint eccentricity justifies a higher figure.

3.9 Unit in the elevated position

3.9.1 When computing leg stresses with the unit in the elevated position, the maximum overturning load and maximum shear load on the unit, using the most adverse combination of applicable variable loadings together with the environmental design loadings, are to be considered with the following criteria:

(a) **Wave forces**: Values of drag coefficient, C_D, and inertia coefficient, C_m, vary considerably with Reynolds number, R_n, and Keulegan-Carpenter number, N_k, and are to be carefully chosen to suit the individual circumstances. In calculating the wave forces using acceptable wave theories, values as given in (i) to (iii) for the hydrodynamic coefficients C_D and C_M, for non-tubular members of the leg chords may be used essentially in the drag dominated regime with post-critical R_n and high N_k. Otherwise more detailed information based on tests or published data is to be used.

(i) Cylindrical chord members with protruding racks:
Drag coefficient,

$$C_D = C_d + \frac{(D_E - D_C)}{D_C} (2 \sin\theta)$$

For marine fouled members, C_D calculated is to be factored by 1,2.
Inertia coefficient,

$$C_M = C_m \left(\frac{A_g}{A_C}\right)$$

where
C_d = the drag coefficient used for a smooth cylinder member
C_m = the inertia coefficient used for a cylinder member
D_E = pitch distance of the racks
D_C = nominal diameter of the cylindrical part of the member
A_g = the cross-sectional area of the member
A_c = the cross-sectional area of the cylindrical part of the member
= the angle between the flow direction and the central line of the cross-section along the racks

(ii) Triangular chord members:
Drag coefficient, for smooth triangular members:
C_D = 1,6 θ = 0°
C_D = 1,4 θ = 45°
C_D = 1,8 θ = 90°
C_D = 1,7 θ = 135°
C_D = 1,3 θ = 180°
For marine fouled members, the C_D values are to be factored by 1,2.
Inertia coefficient, C_M = 1,4
where
θ = Relative approach angle of flow, 0° being towards the backplate and to be counted clockwise.

(iii) Other shapes of non-tubular members: C_D, C_M values should be assessed based on the relevant published data or appropriate tests. The tests should consider possible roughness, Keulegan-Carpenter and Reynolds numbers dependence.

(b) **Dynamics**: Due account of dynamics is to be taken in computing leg stresses when this effect is significant. The following governing aspects are to be included:
(i) The mass and mass distribution of the unit. This includes structural mass, mass of equipment and variable load on board, added mass due to the surrounding water and marine growth, if applicable, etc.
(ii) The global unit structural stiffness. This includes stiffness contributions from the leg to hull connections and the footing interface, if applicable.
(iii) The damping. This includes structural damping, foundation damping and hydrodynamic damping.

(c) **Other considerations**: Other considerations in computing leg stresses include:
(i) Forces and moments due to initial leg inclination and lateral frame deflections of the legs.
(ii) Bending moments at leg/hull connections due to hull sagging under gravity loads.

3.10 Legs in field transit conditions

3.10.1 In field transit conditions within the same geographical area, legs are to be designed for acceleration forces caused by a 6° single amplitude of roll or pitch at the natural period of the unit, plus, 120 per cent of the gravity forces caused by the legs' angle of inclination, unless otherwise verified by appropriate model tests or calculations. The legs are to be investigated for any proposed leg arrangement with respect to vertical position during field transit moves, and the approved positions are to be specified in the Operations Manual. Such investigation is to include strength and stability aspects. Field transit moves may only be undertaken when the predicted weather is such that the anticipated motions of the unit will not exceed the design condition.

3.10.2 The duration of a field transit move may be for a considerable period of time and should be related to the accuracy of weather forecasting in the area concerned. It is recommended that such a move should not normally exceed a twelve hour voyage between protected locations or locations where the unit may be safely elevated. However, during any portion of the move, the unit should not normally to be more than a six hour voyage to a protected location or a location where the unit may be safely elevated. Suitable instructions are to be included in the Operations Manual. Where a special leg position is required for field moves, this position is to be specified in the Operations Manual.

3.11 Legs in ocean transit conditions

3.11.1 In ocean transit conditions involving a move to a new geographical area, legs are to be designed for acceleration and gravity loadings resulting from the motions in the most severe anticipated environmental transit conditions, together with corresponding wind moments. Calculation or model test methods may be used to determine the motions. Alternatively, legs may be designed for the acceleration and gravity forces caused by a design criterion of 20° single amplitude of roll or pitch at a 10 second period. For ocean transit conditions, it may be necessary to reinforce or support the legs, or to remove sections of them. The approved condition is to be included in the Operations Manual.

3.12 Legs during installation conditions

3.12.1 When lowering the legs to the sea bed, the legs are to be designed to withstand the dynamic loads which may be encountered by their unsupported length just prior to touching the sea bed and also to withstand the shock of touching bottom while the unit is afloat and subject to wave motions.

3.12.2 Instructions for lowering the legs are to be clearly indicated in the Operations Manual. The maximum design motions, bottom conditions and sea state while lowering the legs are to be clearly stated. The legs are not to be lowered in conditions which may exceed the design criteria.

3.12.3 For units without bottom mats, all legs are to have the capability of being preloaded to the maximum applicable combined gravity plus overturning load. The approved preload procedure should be included in the Operations Manual.

3.12.4 Consideration is to be given to the loads caused by a sudden penetration of one or more legs during preloading.

3.13 Stability in-place

3.13.1 When the legs are resting on the sea bed, the unit is to have sufficient positive downward gravity loadings on the support footings or mat to withstand the overturning moment of the combined environmental forces from any direction, with a reserve against the loss of positive bearing of any footing or segment of the area, for each design loading condition. The most critical minimum variable load condition is to be considered for each loading direction and in no case is the variable load to be taken greater than 50 per cent of the maximum and using the least favourable location of the centre of gravity.

3.13.2 The safety factor against overturning is to be at least 1,25 with respect to the rotational axis through the centres of the independent footings at the sea bed. For a unit with a mat type footing, the rotational axis is to be taken at the maximum stressed edge of the mat.

3.13.3 For independent footings, the safety factor against sliding at the sea bed is to be related to the soil condition, but in no case is the safety factor to be taken as less than 1,0.

3.14 Sea bed conditions

3.14.1 Classification will be based upon the designer's assumptions regarding the sea bed conditions. These assumptions are to be recorded in the Operations Manual.

3.14.2 Full details of the sea bed at the operating location are to be submitted to LR for review at the design stage. The effects of scouring on bottom mat bearing surfaces and footings is to be considered, *see* 3.16.3.

3.15 Foundation fixity

3.15.1 For units with independent legs, foundation fixity should not normally be considered for in-place strength analysis of the upper parts of the leg in way of the lower guides unless justified by proper investigation of the footing and soil conditions.

3.15.2 For in-place analysis, the lower parts of the leg with independent footings are to be designed for a leg moment no less than 50 per cent of the maximum leg moment at the lower guides, together with the associated horizontal and vertical loads.

3.16 Bottom mat

3.16.1 When the legs are attached to a bottom mat, the scantlings of the mat are to be specially considered, but the permissible stress levels are to be in accordance with Chapter 5. Particular attention is to be given to the attachment, framing and bracing of the mat in order that the loads from the legs are effectively distributed into the mat structure.

3.16.2 Mats and their attachments to the bottom ends of the legs are to be of robust construction to withstand the shock load on touching the sea bed while the unit is afloat and subject to wave motions.

3.16.3 The effects of scouring on the bottom bearing surfaces should be considered by the designer, with a stated design figure for loss of bearing area. The effects of skirt plates, where provided, may be taken into account, *see also* 3.14.1.

3.16.4 The minimum local scantlings of the mat structures are to comply with 3.17.5 and 3.17.6.

3.17 Independent footings

3.17.1 Independent footings are to be designed to withstand the most severe combination of overall and local loadings to which they may be subjected, *see also* 3.16.3. In general, the primary structure is to be analysed by a three-dimensional finite element method.

3.17.2 The complexity of the mathematical model together with the associated element types is to be sufficiently representative of all parts of the primary structure to enable internal stress distributions to be established.

3.17.3 The loading combinations considered are to represent all modes of operation so that the critical design cases are established, and are to include, but not be limited to, the following:

(a) The maximum preload concentrated or distributed over the area of initial contact.
(b) The maximum preload uniformly distributed over the entire bottom area.
(c) The relevant preload distributed over contact areas corresponding to intermediate levels of penetration, as required.
(d) The greatest leg load due to the specified environmental maxima applied over the entire bottom area, with the pressure varying linearly from zero at one end to twice the mean value at the other end.
(e) The distribution in (d) applied in different directions, depending on structural symmetry, to cover all possible wave headings.
(f) Where it is intended to move the unit without the footings being fully retracted, a special analysis of the leg to spudcan connections may be required.

3.17.4 The permissible stresses are to be based on the safety factors for yield and buckling as defined in Ch 5,2. The preload cases may be considered as load case (a) in Ch 5,2 while the loadings associated with the maximum storm cases may be taken as load case (b) in Ch 5,2.

3.17.5 The minimum local scantlings of the bottom shell and stiffening and other areas subjected to pressure loading are to be determined from the formulae for tank bulkheads given in Ch 6,7. The loadhead h_4 should be consistent with the maximum bearing pressure, determined in accordance with 3.17.3, and the wastage allowance of the plating should be not less than 3,5 mm, *see also* 3.17.6.

3.17.6 Where it is intended to operate at a fixed location for the design life of the unit, the footing/leg structure which is below the mud line or internal areas of the footings which cannot be inspected are to have their structure designed with adequate corrosion margins and protection. The corrosion allowance for wastage and the means of protection are to be to the satisfaction of LR and are to be agreed at the design stage.

3.17.7 When the structure consists of compartments which are not vented freely to the sea, the scantlings of the shell boundaries and stiffening are not to be less than required for tank boundaries in Ch 6,7 using the load head h_4 not less than $1{,}4T_0$ m, where T_0 is defined in Ch 1,5.

3.17.8 Where the legs of the unit are made from steel with extra high tensile strength, special consideration is to be given to the weld procedures for the leg to footing connections. Adequate preheat should be used and the cooling rate should be controlled. Any non-destructive examination of the welds should be carried out after a minimum of 48 hours have elapsed after the completion of welding.

3.18 Lifeboat platforms

3.18.1 When self-elevating units are fitted with cantilevered lifeboat platforms, the strength of the platforms is to comply with 1.9. If the lifeboat platform can be subjected to wave impact forces in transit conditions, the scantlings are to be specially considered and details are to be submitted for consideration by LR.

3.19 Topside structure

3.19.1 General requirements for topside structure are given in 1.10.

■ *Section 4* Surface type units

4.1 General

4.1.1 The hull structural design requirements of permanently moored/disconnectable ship units with hull construction in steel engaged in hydrocarbon production and/or storage/offloading at offshore locations are given in Part 10.

4.1.2 Units which operate as shuttle oil tankers will be assigned class in accordance with the Rules for Ships.

4.1.3 The hull structural design requirements of surface type units engaged in drilling and support activities are given in 4.2.

4.2 Surface type units for drilling and support activities

4.2.1 In general, hull strength, scantlings and arrangements for surface type units are to comply with the relevant requirements of the Rules for Ships as applicable to the service of the unit. For drilling units, the local design heads to be used for the derivation of scantlings for walkways and access areas, work areas and storage areas are not to be less than as shown in Table 6.2.1 in Chapter 6.

4.2.2 All aspects which relate to the specialised offshore function of the unit are to be considered on the basis of these Rules, *see also* Pt 3 Ch 1. Additional requirements related to the design arrangements and function of drilling and production units given in Pt 3, Ch 13 and Ch 3 are to be complied with.

4.2.3 **Drilling well/Moonpool**. The hull structure in way of the drilling well is to be suitably strengthened so as to ensure continuity of the required longitudinal strength.

4.2.4 **Structural analysis**. For surface type units, the strength of primary structures of hull compartments and of deck supporting structures, including longitudinal and transverse bulkheads, is to be assessed in accordance with relevant LR *ShipRight SDA Procedures*.

4.2.5 **Fatigue design**. Fatigue damage due to cyclic loading is to be considered. The nature and extent of the fatigue analysis will depend on the mode and area of operation. For details of the fatigue required analyses, *see* Ch 5,5.

4.2.6 The scantlings and arrangements of units with a limited number of tanks for bulk storage of flammable liquids having a flash point not exceeding 60°C (closed-cup test) will be specially considered. Double hull construction in bulk oil tank storage regions will normally be required, *see also* Pt 3, Ch 3.

4.2.7 Additional requirements related to the design function of the unit are given in Part 3.

■ *Section 5* Buoy units

5.1 General

5.1.1 This Section outlines the structural design requirements of buoys of any shape or form. For deep draught caissons, *see* Section 7.

5.1.2 Additional requirements for particular unit types related to the design function of the unit are also given in Part 3.

5.1.3 The hull structure of buoy units is to be divided into watertight compartments and is to have adequate buoyancy and floating stability in all conditions defined in 5.6.2.

5.1.4 Venting arrangements are to be fitted to all tanks or floodable spaces to ensure that air is not trapped in any operating mode, *see* Pt 5, Ch 13.

5.1.5 Venting of void spaces is normally to comply with Pt 5, Ch 13. Special consideration is to be given to small void spaces.

5.1.6 Any spaces filled with foam or permanent ballast is to be specially considered with regard to the materials and their attachment to the structure.

5.1.7 Hull construction and arrangements of buoys used for the storage of oil in bulk storage tanks are to comply with the requirements of the applicable Coastal State Authority.

5.1.8 The requirements of Pt 3, Ch 3 and Ch 13 are to be complied with, as applicable.

5.2 Environmental considerations

5.2.1 The Owner or designer is to specify the environmental criteria for which the installation is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters, *see* Ch 3,4.

5.2.2 A full list of operating and extreme environmental limiting conditions is to be submitted. This is to include the following cases, as applicable, and any other conditions relevant to the system under consideration:
- Extreme survival storm condition.
- Worst environmental conditions in which a ship/unit may remain moored to an installation.
- Worst environmental conditions in which the main operating functions may be carried out (e.g., transfer of product through riser).
- Worst environmental conditions in which a ship/unit may moor on arrival at an off-loading installation.
- Worst environmental conditions in which a disconnectable ship/unit may remain connected.

5.2.3 Environmental factors for mooring systems are to be in accordance with Pt 3, Ch 10.

5.3 Water depth

5.3.1 The minimum and maximum still water levels at the operating location are to be determined, taking full account of the tidal range, wind and pressure surge effects. Data is to be submitted to show the variation in water depth in way of the installation. This data is to be referenced to a consistent datum and is to include, where relevant, the water depth in way of each anchor or pile, gravity base or foundation, pipeline manifold, and in way of the radius swept by a ship/unit attached to the mooring installation.

5.4 Design environmental conditions

5.4.1 The design is to be considered for the following environmental conditions:
- Extreme storm survival condition.
- Maximum connected condition, *see* 5.2.2.
- Other conditions are to be considered, as defined in Table 4.5.1.

Table 4.5.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 4	(d) *See* Note 4
Site installation, *see* Note 3	✓	✓		
Operating, *see* Note 2	✓	✓	✓	✓
Survival	✓	✓	✓	✓
Transit (loadout), *see* Note 3	✓	✓		

NOTES
1. For definition of loading conditions (a) to (d), *see* Ch 3,4.3.
2. For operating conditions, the load cases are to include those defined in 5.2.2, as applicable.
3. For loading conditions (a) and (b) for installation and transit conditions, *see* 5.6.8.
4. For loading conditions (c) and (d) as applicable to buoy units, *see* 5.6.9.

5.4.2 **Extreme storm survival condition**. In general, the individual environmental factors (wind, wave and current) are to have an average recurrence period of not less than 100 years. The joint probability of occurrence of extreme values of individual environmental factors is to be taken into account where sufficiently accurate data exists.

5.4.3 **Maximum connected conditions**. The maximum environmental conditions during which disconnectable ships/units will remain connected to the buoy.

5.4.4 Account is also to be taken in the design of the maximum conditions during which particular operational activities or marine operations are intended to be carried out, e.g., production through risers, transfer of product, connection to or disconnection from single-point mooring. Appropriate limits are to be set and defined in the Operations Manual.

5.5 Environmental loadings

5.5.1 The environmental loading on the installation and its motion responses are to be determined and the dynamic effects are to be considered, *see* Ch 3,4. Account is to be taken of the following:

(a) Environmental loads and motions are to be established by model testing and suitable calculation methods.
(b) Satisfactory correlation between the calculation method and representative model test results is to be demonstrated.
(c) The possibility of resonant motion is to be fully investigated, taking second order wave forces into account.
(d) In determining environmental loads, account is to be taken of the effect of marine growth. Both an increase in the dimensions of submerged members and the change in surface characteristics are to be considered.
(e) Shallow water effects are to be considered where appropriate.
(f) consideration should be given to performing a full coupled analysis of the buoy, mooring and transfer lines, or risers in the case of deep water buoy units.

5.6 Structural design

5.6.1 The general requirements for structural design are given in Chapter 3 but the additional requirements of this Chapter are to be complied with.

5.6.2 The structure is to be designed to withstand the static and dynamic loads imposed on the unit in transit (loadout), site-specific installation, survival and operating conditions. All relevant loads as defined in Chapter 3 are to be considered.

5.6.3 Account is to be taken of slam effects when calculating wave loads in the splash zone.

5.6.4 Local forces from mooring lines and risers are to be included in the analyses for normal operating conditions.

5.6.5 All bearings, guide rollers, etc., forming part of a turntable or other swivel arrangement associated with risers, moorings or pipeline systems on the buoy are to comply with the requirements given in Pt 3, Ch 13,6.

5.6.6 Permissible stresses due to the overall and local effects are to be in accordance with Chapter 5. The minimum local scantlings of the unit are to comply with Chapter 6.

5.6.7 All modes of operation are to be investigated and the relevant design load combinations defined in Ch 5,1.2 are to be complied with. The loading conditions applicable to buoy type units are shown in Table 4.5.1.

5.6.8 Although buoy units will not be classed during transit (loadout) and during the installation procedure at the operating location, the transit condition and the site-specific installation condition are to be investigated and submitted to LR.

5.6.9 The general requirements for investigating accidental loads are defined in Ch 3,4.16. In operating and survival conditions, collision loads against the buoy structure will normally cause only local damage to the structure and consequently loading conditions (c) and (d) in Table 4.5.1 need not be investigated from the overall strength aspects.

5.7 Buoy structure

5.7.1 Buoys are to be designed to withstand the forces and moments resulting from the overall loadings together with the forces and moments due to local loadings, including internal and external pressures.

5.7.2 In general, internal spaces within the buoy are to be designed for the pressure heads defined in Ch 3,4.14. The minimum head on shell boundaries is generally not to be less than 6 metres, *see also* 7.5.5. Special consideration will be given to accepting a reduced design head in benign environments where this can be clearly demonstrated.

5.7.3 The minimum scantlings of shell boundaries including moon pools are to comply with Ch 6,3.4.

5.7.4 The general requirements for watertight and tank bulkheads are to comply with Ch 6,7. The scantlings of the boundaries of internal watertight compartments adjacent to the sea which are required for buoyancy and stability to support the structure are to comply with the requirements for tank bulkheads.

5.7.5 The supports for riser systems and mooring systems are to comply with Chapter 6.

5.8 Topside structure

5.8.1 The scantlings of deck support structures which are designed as a trussed space frame structure are to be determined by analysis. *See also* 1.10.

5.8.2 The minimum scantlings of decks are to comply with Ch 6,4.

5.8.3 The scantlings of superstructures and deckhouses are to comply with Ch 6,9.

5.9 Lifeboat platforms

5.9.1 The strength of lifeboat platforms is to be determined in accordance with the requirements of 1.9.

5.10 Fatigue

5.10.1 The structure of buoys and highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures are to be assessed for fatigue damage due to cyclic loading.

5.10.2 The general requirements for fatigue design and the factors of safety on fatigue life are to comply with Ch 5,5.

Section 6
Tension-leg units

6.1 General

6.1.1 This Section outlines the structural design requirements of tension-leg units as defined in Pt 1, Ch 2,2. Additional requirements for particular unit types related to the design function of the unit are given in Part 3.

6.1.2 The requirements of Section 1 for semi-submersible units are to be complied with as applicable.

6.1.3 The term 'tension-leg' used in this Section includes all the component parts of the pre-tensioned mooring system in one group and includes the top connections to the unit and the bottom connections to the sea bed foundation. Each unit will have a number of tension legs. Each tension leg may be made up of individual tensioned cables or members which are referred to in this Section as 'tethers'.

6.2 Air gap

6.2.1 Unless the upper hull structure is designed for wave impact, a clearance 'air gap' of 1,5 metres between the underside of the upper hull deck structure and the highest predicted design wave crest is to be maintained during operation on station. Calculations, model test results or prototype reports are to be submitted for consideration.

6.2.2 In cases where the unit is designed without an adequate air gap in accordance with 6.2.1, the scantlings of the upper hull deck structure are to be designed for wave impact forces. If the whole hull structure is waterborne, the scantlings are to be specially considered but they are not to be less than would be required for a semi-submersible unit.

6.3 Loading and environmental considerations

6.3.1 The Owner or designer is to specify the environmental criteria for which the installation is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters, *see* Ch 3,4.

6.3.2 The environmental loading on the installation and its motion responses are to be determined and the dynamic effects are to be considered, *see* Ch 3,4.

6.3.3 When determining the critical design loadings on tethers, realistic combinations of environmental loadings and unit response are to be taken into account. All loadings and unit motions are to be agreed with LR and the full range of operating draughts are to be considered.

6.3.4 Motions may be determined by a suitable combination of model tests and calculation methods.

6.3.5 The possibility of resonant motions is to be fully investigated, taking a second order wave and wind forces into account. The likelihood of the occurrence of rotational and vertical oscillations is to be particularly considered.

6.3.6 In determining environmental loads, account is to be taken of the effect of marine growth. Both an increase in the dimensions of submerged members and the change in surface characteristics are to be considered.

6.3.7 When carrying out model testing, the test programme and the model test tank facilities are to be to the satisfaction of LR and account is to be taken of the following:
- The relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined.
- The tests are to be of sufficient duration to establish low frequency motion behaviour.

6.4 Structural design

6.4.1 The general requirements for structural design are given in Chapter 3, and the requirements of Section 1 for semi-submersible units are to be complied with, except where modified by this Section.

6.4.2 The following effects are to be considered when investigating loading conditions that could lead to fatigue of the structure, tension legs or foundations:
- Variations of combined wave and current to ensure that all damaging stress levels are likely to be included in the analysis.
- Member loading including the effects of varying buoyancy and/or flooding due to wave motions in the splash zone.
- Cyclic loading due to wind and the operation of machinery, where significant.
- Still water loading condition at mean draught.

6.4.3 All modes of operation are to be investigated and the relevant design load combinations defined in Ch 5,1.2 are to be complied with. The loading conditions applicable to a tension-leg unit are shown in Table 4.6.1.

6.4.4 The permissible stresses are to be in accordance with Chapter 5 and the minimum local scantlings of the unit are to comply with Chapter 6.

6.4.5 Although a tension-leg unit will not be classed in the transit condition and during site installation, the transit condition and the site-specific installation condition are to be investigated and submitted to LR.

6.4.6 The general requirements for investigating accidental loads are defined in Ch 3,4.16. In operating and survival conditions, collision loads against the hull structure will normally only cause local damage to the structure without heeling, and consequently loading conditions (c) and (d) in Table 4.6.1 need not be investigated from the overall strength aspects.

Table 4.6.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 4	(d) *See* Note 4
Site installation, *see* Note 3	✓	✓		
Operating, *see* Note 2	✓	✓	✓	✓
Survival, *see* Note 2	✓	✓	✓	✓
Transit (loadout), *see* Note 3	✓	✓		

NOTES
1. For definition of loading conditions (a) to (d), *see* Ch 3,4.3.
2. For operating conditions, the load cases are to include those defined in 5.2.2 as applicable.
3. For loading conditions (a) and (b) for site installation and transit conditions, *see* 6.4.5.
4. For loading conditions (c) and (d) as applicable to tension-leg units, *see* 6.4.6.

6.5 Tension-leg materials

6.5.1 The materials used for tension legs are to be specially considered and the materials used are to comply with the following requirements:

(a) The corrosion protection is to be adequate for the life of the installation.
(b) The materials and their attachments to the structure are to be suitable for their purpose and have adequate fatigue life.
(c) The strength, elasticity and flexibility of the tension legs are to be sufficient to accommodate the design extreme motions of the installation and the dynamic patterns which may be encountered over the whole range of environmental criteria.
(d) The material grades used for tension legs, fittings and attachments to the structure are to have adequate resistance to brittle fracture.

6.5.2 Adequate test data is to be submitted to LR to demonstrate that the materials and fittings used for tension legs will have adequate service life. The design philosophy relating to the life and replacement of tension legs and their fittings is to be clearly stated at the design stage.

6.6 Tension-leg design

6.6.1 When reference to tension legs is made in this sub-Section, the Rules apply to tethers constructed of wire ropes, tubes or any other equivalent section.

6.6.2 The leg system is to be fail-safe, in that failure of a single tension-leg member at any time during the life of the installation will not induce stress levels in any other tension-leg member that will produce fatigue failure in that member or its associated fittings in less than one year, assuming average winter conditions, or induce increased accumulated fatigue damage to reduce significantly the overall fatigue life of the system.

6.6.3 In general, each tension leg is to be assembled from tether members of only one type and size. The cross-section of tension leg members may vary in a consistent manner over depth. The fitting of materials having different elastic constants in parallel load-carrying components of a tension leg will not normally be accepted.

6.6.4 All leg tether members forming any one tension leg are to be set to an approximate common tension. Suitable means of adjusting the tensions of the individual components of each leg are to be provided at the upper end of each individual tether.

6.6.5 Means are to be provided for monitoring the tensions in tension-leg components.

6.6.6 The design is to be such that, with suitable ballasting, the minimum tension in any tether can be adjusted to be not less than five per cent of the normal pre-tension. A lesser tension is not normally permitted. Where the Owner requests a relaxation of this requirement, appropriate dynamic analysis is to be carried out to evaluate the tether design.

6.6.7 No end terminal or other fitting associated with the tension legs is to be dependent upon the maintenance of the leg tension to retain it in place.

6.6.8 In general, all leg connections including pins, bearings, locks, etc., are to be arranged by positively activated wedging systems, or otherwise, so that there are no slack fits or non-essential clearances. Screwed and bolted fittings are to be provided with positive locking arrangements.

6.6.9 Arrangements are to be made to prevent kinking and sharp bends in tether members in way of the end fittings. In determining the maximum angles that may be assumed by the leg members in way of end fittings, account is to be taken of the maximum extent of snaking or other dynamic distortions of the legs that could occur in extreme environmental conditions.

6.6.10 The effects of scuffing and wear of tethers within rope guides, bell mouths and other systems due to the movement of leg components caused by motions of the unit are to be taken into account in the design.

6.6.11 The extreme maximum and minimum tether loads, which determine the tether design requirements, are to be calculated.

6.6.12 Tether misalignment where tethers are not completely vertical and parallel are to be taken into account.

6.6.13 The maximum tether load is to be determined at the top of the tether with the unit at its minimum design storm weight and with the highest water level. The calculation is to include the effects of the worst combination of the horizontal centre of gravity position, wave loading, wind and current loading, tether misalignment and dynamic response and platform motions.

6.6.14 The minimum tether load is to be determined at the bottom of the tether with the unit at its maximum design storm weight and at the lowest water level. The calculation is to include the effects of the worst combination of the horizontal centre of gravity position, wave loading, wind and current loadings, tether misalignment and dynamic response, platform motions, catenary effects of tethers and the design margin.

6.6.15 When calculating the minimum tether load, a design margin of five per cent of the nominal pre-tension is to be applied.

6.6.16 The unit with the most unfavourable combination of weight, centre of gravity and buoyancy is to be capable of surviving the worst design damage condition. The requirements for watertight and weathertight integrity are to comply with Chapter 6.

6.6.17 After flooding of any compartment as required to satisfy 6.6.16, the requirements of 6.6.15 are to be complied with.

6.6.18 Within a period of 12 hours from commencement of any accidental flooding, the loading of the unit is to be adjusted, as necessary, so that the tensions of all tethers at their lower ends remain positive under the most unfavourable environmental conditions which could be expected to occur at the location within a return period of not less than one year. The loading adjustment may be means of deballasting, and/or removal, dumping or horizontal movement of deck loads.

6.7 Tension-leg permissible stresses

6.7.1 The maximum permissible stresses in steel tethers under the worst combination of steady and dynamic loadings are to comply with the following factors of safety based on the tensile yield stress of the material:

(a) With all tethers in a tension-leg group in operation:
- 1,67 for tension.
- 1,43 for combined ‘comparative’ stress.

(b) With one tether in a tension-leg group non-operational:
- 1,25 for tension.
- 1,11 for ‘comparative’ stress.

6.8 Tension-leg fatigue design

6.8.1 In the design of tether components, consideration is to be given to the fatigue damage that will result from cyclic stresses. A detailed fatigue analysis is to be performed. The combined axial and bending stress is to be determined by dynamic analysis and is to consider variations around the tether circumference.

6.8.2 Where the tethers are built up of various components such as screwed sections or chain link, the effect of many tether components being connected in series is to be adequately accounted for in the design fatigue life.

6.8.3 The fatigue life of tethers and their end connections and the factors of safety on the calculated design fatigue life are to comply with the requirements of Ch 5,5.

6.9 Tension-leg foundation design

6.9.1 The sea bed and soil conditions at the proposed locations of the tension-leg foundations are to be determined to provide data for the design of the foundation system. Requirements for site investigation are contained in Pt 3, Ch 14.

6.10 Piled foundations

6.10.1 This sub-Section applies to piles which are either driven or drilled and grouted into the sea bed to provide resistance to axial, lateral and torsional loading. Piles installed by vibrating hammers are not recommended.

6.10.2 Piles are characterised by being relatively long and slender and having a length to diameter or width ratio generally greater than 10.

6.10.3 The pile design is to be approved by LR.

6.10.4 The pile is to be designed to provide sufficient ultimate capacity to resist the maximum applied axial, lateral and torsional loads with appropriate factors of safety based on a working stress design approach.

6.10.5 Table 4.6.2 defines the design case and factors of safety to be used for piles for a tension-leg foundation system. Table 4.6.2 does not apply to axial capacity of piles installed by vibrating hammers.

Table 4.6.2 Minimum factors of safety for piles for a tension-leg foundation system

Design case	Factor of safety	
	Axial loading	Lateral loading
Operating	2,7	2,0
Extreme storm	2,0	1,5

6.10.6 The factors of safety given in Table 4.6.2 are applicable to pile groups for tension-leg foundation systems. Individual piles within a group are to achieve a minimum factor of safety of 1,5.

6.10.7 The possible variation in inclination of the applied loading to the pile is to be taken into account.

6.10.8 Consideration is to be given to the effects of cyclic loading on pile capacity.

6.10.9 Consideration is to be given to long-term changes to soil stresses around the pile and upward creep.

6.10.10 Consideration is to be given to performing special tests, such as centrifuge model tests, to provide a better understanding of pile behaviour.

6.10.11 The pile response under axial, lateral and torsional loading is to be determined to ensure that deflections and rotations remain within tolerable limits.

6.10.12 Consideration is to be given to the possible formation of a posthole at the pile head and its effect on axial capacity.

6.10.13 Consideration is to be given to the possible scouring of sea bed soils around the suction pile and its effect on capacity.

6.10.14 No account shall be taken of soil suction at the pile tip or the effect of rate of loading.

6.10.15 Analysis of the pile/soil interaction response is to take into account the non-linear stress/strain behaviour of the foundation soils and the stress history and cyclic loading effects on soil resistance. Allowance is to be made for the response of different soil types.

6.10.16 An acceptable basis for pile design and installation is contained in Pt 3, Ch 14.

6.10.17 The pile is to have sufficient strength to account for axial and bending stresses due to extreme, operating and installation loading conditions in accordance with Pt 3, Ch 14.

6.10.18 Details of the proposed method of pile installation are to be submitted. Consideration is to be given to the tolerances associated with pile verticality.

6.10.19 Consideration is to be given to the provision of a monitoring system for the measurement of long-term vertical movements of the piles relative to the surrounding soil.

6.11 Suction piled foundations

6.11.1 This sub-Section applies to piles which are installed by suction to achieve the required penetration into the sea bed to provide resistance to axial, lateral and torsional loading. Suction is applied by creating a reduced water pressure within the pile compared to the external ambient water pressure. Suction piles can be retrieved from the sea bed by reversing the suction process.

6.11.2 Suction piles are characterised by having a large diameter and a length to diameter ratio generally less than three and are essentially caisson type foundations.

6.11.3 The suction pile design is to be approved by LR.

6.11.4 The suction pile is to be designed to provide sufficient ultimate capacity to resist the maximum applied axial, lateral and torsional loads with appropriate factors of safety based on a working stress design approach.

6.11.5 Table 4.6.3 defines the design case and factors of safety to be used for suction piles for a tension-leg foundation system.

Table 4.6.3 Minimum factors of safety for suction piles for a tension-leg foundation system

Design case	Factor of safety	
	Axial loading	Lateral loading
Operating	2,7	2,0
Extreme storm	2,0	1,5

6.11.6 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of suction piles. The installation tolerances are to be considered when assessing failure modes for the soil.

6.11.7 The possible variation in inclination of the applied loading to the suction pile is to be taken into account.

6.11.8 Consideration is to be given to the effects of cyclic loading on suction pile capacity.

6.11.9 Consideration is to be given to long-term changes to soil stresses around the suction pile and upward creep.

6.11.10 Consideration is to be given to performing special tests, such as centrifuge model tests, to provide a better understanding of suction pile behaviour.

6.11.11 The suction pile response under axial, lateral and torsional loading is to be determined to ensure that deflections and rotations remain within tolerable limits.

6.11.12 Consideration is to be given to the possible formation of a posthole at the pile head and its effect on axial capacity.

6.11.13 Consideration is to be given to the possible scouring of sea bed soils around the suction pile and its effect on capacity.

6.11.14 No account shall be taken of soil suction at the pile tip or the effect of rate of loading unless the suction pile is provided with a cap and suction can be justified based on rate of loading and soil permeability.

6.11.15 Analysis of the suction pile/soil interaction response is to take into account the non-linear stress/strain behaviour of the foundation soils and the stress history and cyclic loading effects on soil resistance. Allowance is to be made for the response of different soil types.

6.11.16 An acceptable basis for suction pile design and installation is contained in Pt 3, Ch 12.

6.11.17 The suction pile is to have sufficient strength to account for the stresses due to extreme, operating and installation loading conditions, in accordance with Pt 3, Ch 12. Where necessary, a detailed finite element stress analysis is to be carried out.

6.11.18 Details of the proposed method of suction pile installation are to be submitted. Consideration is to be given to the tolerances associated with suction pile verticality and also to the internal soil heave.

6.11.19 Consideration is to be given to the provision of a monitoring system for the measurement of long-term vertical movements of the suction piles relative to the surrounding soil.

6.12 Gravity foundations

6.12.1 This sub-Section applies to gravity foundations which rely on their mass to provide resistance to vertical, lateral and torsional loading. Gravity foundations may be provided with skirts which penetrate the sea bed to provide increased lateral resistance.

6.12.2 The gravity foundation design is to be approved by LR.

6.12.3 The gravity foundation is to be designed to provide sufficient ultimate capacity to resist the maximum applied vertical, lateral and torsional loads with appropriate load and material coefficients based on a load and resistance factor design approach.

6.12.4 The material coefficient for soil is to be taken as 1,25.

6.12.5 Appropriate load coefficients are to be specially considered for particular applications for tension-leg foundation systems.

6.12.6 Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of gravity foundations. The installation tolerances are to be considered when assessing failure modes for the soil.

6.12.7 The possible variation in inclination of the applied loading to the gravity foundation is to be taken into account.

6.12.8 Consideration is to be given to the effects of cyclic loading on gravity foundation capacity.

6.12.9 Consideration is to be given to performing special tests, such as centrifuge model tests, to provide a better understanding of gravity foundation behaviour.

6.12.10 The gravity foundation response under vertical, lateral and torsional loading is to be determined to ensure that deflections and rotations remain within tolerable limits.

6.12.11 Consideration is to be given to the possible scouring of sea bed soils around the gravity foundation and its effect on capacity.

6.12.12 No account shall be taken of soil suction or the effect of rate of loading.

6.12.13 Analysis of the gravity foundation/soil interaction response is to take into account the non-linear stress/strain behaviour of the foundation soils and the stress history and cyclic loading effects on soil resistance. Allowance is to be made for the response of different soil types.

6.12.14 An acceptable basis for gravity foundation design and installation is contained in Pt 3, Ch 14.

6.12.15 The gravity foundation is to have sufficient strength to account for the stresses due to extreme, operating and installation loading conditions in accordance with Pt 3, Ch 14. Where necessary, a detailed finite element stress analysis is to be carried out.

6.12.16 Details of the proposed method of gravity foundation installation are to be submitted. Consideration is to be given to the tolerances associated with gravity foundation inclination and orientation and skirt penetration, if applicable.

6.13 Mechanical components

6.13.1 Essential mechanical components are to be designed such that the components are capable of being condition monitored, repaired and/or replaced. Prototype testing may be required for specialised components or novel design arrangements.

6.14 Monitoring in service

6.14.1 The tether system is to be suitably instrumented and monitored in service to ensure that the system is performing within design limitations.

6.14.2 Provision is to be made to monitor tether top tensions. In addition, it is recommended that the platform mean offset position and the upper and/or lower flexible joint angles of tethers are monitored.

6.15 Tether replacement

6.15.1 Tethers are to be inspected at Periodical Surveys and the Owner/designer is to prepare a planned procedure for inspection, retrieval and replacement of tethers in the event of damage or as part of a planned schedule.

6.15.2 The replacement procedures involved are to be clearly documented with regard to the retrieval method, equipment required and unit operations. The procedures are to be included in the unit's Operations Manual.

6.15.3 It is recommended that an adequate number of spare parts of tethers and mechanical fittings are supplied to the unit and made available during its service life.

■ *Section 7* Deep draught caisson units

7.1 General

7.1.1 This Section outlines the structural design requirements of deep draught caisson units and similar floating installations as defined in Pt 1, Ch 2,2, but excluding other unit types defined in this Chapter.

7.1.2 Additional requirements for particular unit types related to the design function of the unit are also given in Part 3.

7.1.3 The hull of caisson units are to be divided into watertight compartments and have adequate buoyancy and floating stability in all conditions defined in 7.5.2.

7.1.4 Watertight compartments which are to be temporarily flooded during site installation or in upending conditions are to have tank bulkhead scantlings as required by Ch 6,7.

7.1.5 Venting arrangements are to be fitted to all floodable spaces to ensure that air is not trapped in any operating mode or temporary condition.

7.1.6 Any spaces filled with permanent ballast are to be specially considered with regard to the material and its attachment to the structure.

7.1.7 Production and oil storage units are to comply with the requirements of Pt 3, Ch 3. Caissons designed for the storage of oil in bulk storage tanks are to comply with the relevant requirements of the National Authority.

7.2 Air gap

7.2.1 In all floating modes of operation, the unit is to be designed to have a clearance air gap between the underside of the top side deck structure and the highest predicted design wave crest. Model test results are to be submitted for consideration.

7.3 Environmental loadings

7.3.1 The Owner or designer is to specify the environmental criteria for which the installation is to be approved. The extreme environmental conditions applicable to the location are to be defined, together with all relevant operating environmental limits. Full particulars are to be submitted with sufficient supporting information to demonstrate the validity of the environmental parameters, *see* Ch 3,4.

7.3.2 Although a deep draught caisson unit will not be classed during transit and during the installation procedure at the operating location, the specified limiting design environmental criteria for transit/loadout, upending, and mating conditions for which LR structural approval is required are to be clearly defined and submitted.

7.3.3 Environmental loads and motions are to be established for each mode of operation, including the upending condition, by suitable analysis. Model tests will normally be required.

7.3.4 In determining environmental loads, account is to be taken of the effect of marine growth, *see* Ch 3,4.13.

7.4 Model testing

7.4.1 The test programme and the model test facilities are to be to LR's satisfaction, *see also* Ch 3,4.

7.4.2 The relative directions of wind, wave and current are to be varied as required to ensure that the most critical loadings and motions are determined. The tests are to be of sufficient duration to establish low frequency motion behaviour.

7.4.3 Model tests are to demonstrate clearly that the air gap as required by 7.2.1 is maintained in all operating modes.

7.5 Structural design

7.5.1 The general requirements for structural design are given in Chapter 3, but the additional requirements of this Chapter are to be complied with.

7.5.2 The structure is to be designed to withstand the static and dynamic loads imposed on the unit and the structural analysis and determination of primary scantlings are to be on the basis of the distribution of loadings expected in all modes of operation and temporary conditions, including loadout, transportation, upending, lifting and mating, as applicable.

7.5.3 All relevant loads as defined in Chapter 3 are to be considered and special attention is to be made in determining vortex-induced action effects due to wind and sea currents. The arrangement and scantlings of helical plate attachments on the hull, where fitted to keep vortex-induced responses at acceptable levels, are to be specially considered. The shell plating in way of attachments is to be increased.

7.5.4 Local forces from mooring lines and risers are to be included in the analyses for normal operating conditions.

7.5.5 Where units have combined crude oil bulk storage and ballast tanks which are intended to remain full in operating conditions, consideration is to be given to taking the design hydrostatic loading as the difference between external and internal pressures subject to adequate safeguards against accidental loading and agreed survey requirements. The corrosion wastage allowance in such tanks is to be specially considered, *see* 7.10.

7.5.6 Permissible stresses due to the overall and local effects are to be in accordance with Chapter 5. The minimum local scantlings of the unit are to comply with Chapter 6.

7.5.7 The relevant design load combinations defined in Ch 4,2.2 are to be complied with. The loading conditions applicable to a caisson unit are shown in Table 4.7.1.

Table 4.7.1 Design loading conditions

Mode	Applicable loading condition			
	(a)	(b)	(c) *See* Note 3	(d) *See* Note 3
Site installation upending/mating, *see* Note 2	✓	✓		
Operating	✓	✓	✓	✓
Survival	✓	✓	✓	✓
Transit (loadout), *see* Note 2	✓	✓		

NOTES
1. For definition of loading conditions (a) to (d), *see* Ch 3,4.3.
2. For loading conditions (a) and (b) for site installation (upending/mating) and transit (loadout) conditions, *see* 7.3.2.
3. For loading conditions (c) and (d) as applicable to caissons, *see* the general requirements stated in 1.3.5 to 1.3.7, as applicable.

7.5.8 The overall strength of the unit is to be analysed by a three-dimensional finite element method in accordance with Ch 3,3.

7.5.9 Where the hull form incorporates a space frame or truss system of braces, the requirements of 1.7 and 1.8 are to be complied with.

7.6 Caisson structure

7.6.1 Caissons are to be designed to withstand the forces and moments resulting from the overall loadings together with the forces and moments due to local loadings, including internal and external pressures.

7.6.2 In general, internal spaces within the caisson are to be designed for the pressure heads defined in Ch 3,4.14. The minimum head on shell boundaries is not to be less than 6 m, *see also* 7.5.5.

7.6.3 The minimum scantlings of shell boundaries including moon pools are to comply with Ch 6,3.4.

7.6.4 The general requirements for watertight and tank bulkheads are to comply with Ch 6,7. The scantlings of the boundaries of internal watertight compartments adjacent to the sea which are required for buoyancy and stability to support the structure are to comply with the requirements for tank bulkheads, *see also* 7.10.

7.6.5 Internal caisson structure supporting main bracings is in general not to be of a lesser strength than the bracing itself.

7.6.6 The supports for riser systems and mooring systems are to comply with Chapter 6.

7.7 Topside structure

7.7.1 The scantlings of deck support structures which are designed as a trussed space frame structure are to be determined by analysis. The requirements of 7.5.9 are to be complied with.

7.7.2 The minimum scantlings of decks are to comply with Ch 6,4.

7.7.3 The scantlings of superstructures and deckhouses are to comply with Ch 6,9.

7.8 Lifeboat platforms

7.8.1 The strength of lifeboat platforms is to be determined in accordance with the requirements of 1.9.

7.9 Fatigue

7.9.1 The structure of deep draught caissons and highly stressed structural elements of mooring line attachments, chain stoppers and supporting structures is to be assessed for fatigue damage due to cyclic loading.

7.9.2 The general requirements for fatigue design and the factors of safety on fatigue life are to comply with Ch 5,5.

7.10 Corrosion protection

7.10.1 The general requirements for corrosion protection are to comply with Part 8.

7.10.2 In tanks referred to in 7.5.5, due to design operating procedures or in areas where it is not considered practicable to inspect internal spaces or replace corrosion protection systems, the structure is to be designed with adequate corrosion margins and protection for the service life of the caisson. The corrosion wastage allowance and protection of all structural components are to be to the satisfaction of LR and agreed at the design stage.

7.10.3 Where practicable, suitable inspection coupons or other inspection aids are to be incorporated into the structure so that the degree of corrosion in inaccessible spaces can be monitored during Periodical Surveys required by Part 1.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 This Section defines the overall strength requirements of the unit and the permissible stresses in all operating modes.

1.1.2 The design loads are to be in accordance with Ch 3,4 and the design conditions are to be based on the most unfavourable combinations of gravity loads, functional loads, environmental loads and accidental loads.

1.1.3 Specific requirements for structural unit types are also defined in Chapter 4.

1.1.4 The local strength of the unit is to comply with the requirements of Chapter 6.

1.1.5 The limiting design environmental and operational conditions for each mode of operation is to be defined by the Owner/designer and included in the Operations Manual, *see* Pt 3, Ch 1,3.

1.2 Structural analysis

1.2.1 A structural analysis of the primary structure of the unit is to be carried out in accordance with the requirements of Chapter 3 and the resultant stresses determined.

1.2.2 The loading conditions are to represent all modes of operation and the critical design cases obtained.

1.2.3 The structure is to be analysed for the relevant load combinations given in Ch 3,4.3.

1.2.4 For the combined load cases applicable to all unit types, *see also* Chapter 4.

1.2.5 The permissible stress levels relevant to the combined load cases defined in 1.2.3 are to be in accordance with Section 2.

1.2.6 Special consideration is to be given to structures subjected to large deformations.

1.3 Primary structure

1.3.1 Local stresses, including those due to circumferential loading on tubular members, are to be added to the primary stresses to determine total stress levels.

1.3.2 The scantlings are to be determined on the basis of criteria which combine, in a rational manner, the individual stress components acting on the various structural elements of the unit. The stresses are to be determined using net scantlings, i.e., no corrosion allowance included, *see also* Pt 3, Ch 1,5.

1.3.3 The critical buckling stress of structural elements is to be considered in relation to the computed stresses, *see* Sections 3 and 4.

1.3.4 Fatigue damage due to cyclic loading is to be considered in the design of the unit in accordance with Section 5.

1.3.5 When computing bending stresses, the effective flange areas are to be determined in accordance with 'effective width', concepts derived from accepted shear lag theories and plate buckling considerations.

1.3.6 Where appropriate, elastic deflections are to be taken into account when determining the effects of eccentricity of axial loading, and the resulting bending moments superimposed on the bending moments computed for other types of loadings.

1.3.7 When computing shear stresses in bulkheads, plate girder webs or hull side plating, only the effective shear area of the plate or web is to be considered. For girders, the total depth of the girder may be considered as the web depth.

1.3.8 Members of lattice type structures may be designed in accordance with a recognised Code as defined in Part 3, Appendix A.

1.4 Connections and details

1.4.1 Special consideration is to be given to structural continuity and connections of critical components of the primary and special structure, such as the following:

- Bracing intersections and end connections.
- Columns to lower and upper hulls.
- Jackhouses to deck.
- Legs to mat or footings.
- Turret areas.
- Yokes and mooring arms.
- Mooring line attachments.
- Swivel stack supports.

1.4.2 Critical joints which depend upon the transmission of tensile stresses through the thickness perpendicular to the plate surface of one of the members are to be avoided wherever possible. Where the stresses perpendicular to the plate surface exceed 50 per cent of the Rule permissible stress and the thickness exceeds 15,0 mm, plate material with suitable through-thickness properties as required by Ch 3,8 of the *Rules for the Manufacture, Testing and Certification of Materials* is to be used.

1.4.3 Welding and structural details are to be in accordance with Chapter 8.

1.5 Stress concentration

1.5.1 The effect of notches, stress raisers and local stress concentrations is to be taken into account in the design of load-carrying elements.

■ *Section 2* Permissible stresses

2.1 General

2.1.1 For the combined load cases, as defined in Ch 3,4.3, the maximum permissible stresses of steel structural members are to be based on the following factors of safety unless otherwise specified:

(a) Load case (a):
- 2,50 for shear (based on the tensile yield stress)
- 1,67 for shear buckling (based on the shear buckling stress)
- 1,67 for tension and bending (based on the tensile yield stress)
- 1,67 for compression (based on the lesser of the least buckling stress or the yield stress)
- 1,43 for combined 'comparative' stress (based on the tensile yield stress).

(b) Load case (b) and (c):
- 1,89 for shear (based on the tensile yield stress)
- 1,25 for shear buckling (based on the shear buckling stress)
- 1,25 for tension and bending (based on the tensile yield stress)
- 1,25 for compression (based on the lesser of the least buckling stress or the yield stress)
- 1,11 for combined 'comparative' stress (based on the tensile yield stress).

(c) Load case (d):
- 1,72 for shear (based on the yield stress)
- 1,0 for shear buckling (based on the shear buckling stress)
- 1,0 for tension and bending (based on the tensile yield stress)
- 1,0 for compression (based on the lesser of the least buckling stress or the yield stress)
- 1,0 for combined 'comparative' stress (based on the tensile yield stress).

2.1.2 For plated structures, the combined 'comparative' stress is to be determined where necessary from the formula:

$$\sigma_{cc} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau^2}$$

where σ_x and σ_y are the combined axial and bending stresses in the X and Y directions respectively, τ is the combined shear stress due to torsion and/or bending in the X-Y plane.

2.1.3 When finite element methods are used to verify scantlings, special consideration will be given to areas of the structure where localised peak stresses occur.

2.1.4 Non linear and plastic design methods may be used for verifying the local structure in load cases (c) and (d), as defined in Ch 3,4.3. Local yielding and permanent deformation can be accepted; however, the structural arrangements must prevent progressive collapse.

2.1.5 The buckling strengths of plates and stiffeners are to comply with Section 3.

2.1.6 The buckling strength for individual primary members subjected to axial compression and combined axial compression and bending is to be in accordance with Section 4.

2.1.7 Permissible stress levels for lattice type structures are to be determined as required by 1.3.8.

2.1.8 Permissible stresses in materials other than steel are to be specially considered.

■ *Section 3* Buckling strength of plates and stiffeners

3.1 Application

3.1.1 The requirements of this Section apply to plate panels, and attached stiffeners subject to overall hull structure compression and shear stresses. The maximum design values computed are to be determined in accordance with 1.2.

3.1.2 For states of stress which cannot be defined by one single reference stress, the buckling characteristics are to be based on recognised interaction formulae.

3.1.3 LR's ShipRight program no. 10206 may be used for the buckling assessment of flat rectangular plate panels by direct calculation.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

E = modulus of elasticity, in N/mm^2 (kgf/mm^2)
= 206 000 N/mm^2 (21 000 kgf/mm^2) for steel

σ_o = specified minimum yield stress, in N/mm^2 (kgf/mm^2)

σ_{CRB} = critical buckling stress in compression, in N/mm^2 (kgf/mm^2), corrected for yielding effects

σ_E = elastic critical buckling stress in compression, in N/mm^2 (kgf/mm^2)

τ_{CRB} = critical buckling stress in shear, in N/mm^2 (kgf/mm^2), corrected for yielding effects

τ_E = elastic critical buckling stress in shear, in N/mm^2 (kgf/mm^2)

τ_o = $\dfrac{\sigma_o}{\sqrt{3}}$

3.3 Elastic critical buckling stress

3.3.1 The elastic critical buckling stress of plating and stiffeners is to be determined in accordance with an agreed Code or Standard or according to Table 4.7.2 and Table 4.7.3 in Pt 3, Ch 4,7, of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

3.4 Scantling criteria

3.4.1 The critical buckling stress in compression, corrected for yielding effects, σ_{CRB}, of plate panels and stiffeners, as derived from Table 4.7.2 and Table 4.7.3 in Pt 3, Ch 4,7 of the Rules for Ships, is to satisfy the following:

$$\sigma_{CRB} \geq F_{SC}\ \sigma_A$$

where

F_{SC} = factor of safety for compression in accordance with 2.1.1 for the appropriate load case.

3.4.2 The critical buckling stress in shear, corrected for yielding effects, τ_{CRB}, of plate panels as derived from Table 4.7.2(c), in Pt 3, Ch 4,7 of the Rules for Ships, is to satisfy the following:

$$\tau_{CRB} \geq F_{SS}\ \tau_A$$

where

F_{SS} = factor of safety for shear buckling in accordance with 2.1.1 for the appropriate load case.

3.4.3 Buckling criteria are to be determined for plating and plate and stiffener combinations, including (but not limited to):

- Flat bar stiffeners.
- Bulb plate stiffeners.
- Rolled angles.
- Built-up profiles.
- Floors or deep girders.

3.4.4 All appropriate buckling modes are to be investigated, including:

- Column buckling.
- Torsional buckling.
- Web and flange buckling.

3.4.5 In general, stresses are to be determined using net scantlings, i.e., no corrosion allowance included.

■ *Section 4* Buckling strength of primary members

4.1 Application

4.1.1 The requirements of this Section are applicable to individual primary structural members which are subjected to axial compression or combined axial compression and bending due to overall loading.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ_o, E as defined in 3.2.1

σ_A = computed axial compressive stress, in N/mm^2 (kgf/mm^2)

σ_B = computed compressive stress due to bending, in N/mm^2 (kgf/mm^2)

F_A = factor of safety for compression, in accordance with 2.1.1

F_B = factor of safety for bending, in accordance with 2.1.1

F_C = factor of safety for overall member buckling, as determined from Table 5.4.2

σ_{CRB} = critical overall member buckling stress, in N/mm^2 (kgf/mm^2), as determined from Table 5.4.1

σ_C = local member critical buckling stress, in N/mm^2 (kgf/mm^2)

σ_{PA} = permissible axial compressive stress, in N/mm^2 (kgf/mm^2)

$= \dfrac{\sigma_o}{F_A}$ or $\dfrac{\sigma_c}{F_A}$ or $\dfrac{\sigma_{CRB}}{F_C}$ whichever is the lesser

σ_{PB} = permissible compressive stress due to bending, in N/mm^2 (kgf/mm^2)

$= \dfrac{\sigma_o}{F_B}$ or $\dfrac{\sigma_c}{F_B}$ whichever is the lesser

D = mean diameter of cylindrical shell, in mm

t = thickness of cylindrical shell, in mm.

4.3 Elastic critical buckling stress

4.3.1 Where the elastic critical buckling stress exceeds 50 per cent of the specified minimum yield stress of the material, the calculated critical buckling stresses are to be corrected for yielding effects and are given by:

$\sigma_C = \sigma_o\,(1 - \sigma_o/4\sigma_E)$ N/mm^2 (kgf/mm^2) in compression.

4.4 Scantling criteria

4.4.1 Individual members are to be investigated for overall critical buckling in accordance with an agreed Code or Standard or Table 5.4.1 and Table 5.4.2 and also for local buckling.

Table 5.4.1 Overall member critical buckling stress

Condition	Member critical buckling stress σ_{CRB}, N/mm^2 (kgf/mm^2)
(a) When $\lambda < \sqrt{\eta}$	$\sigma_o - \dfrac{\sigma_o^2 \lambda^2}{4\pi^2 E}$
(b) When $\lambda \geq \sqrt{\eta}$	$\dfrac{\pi^2 E}{\lambda^2}$
Symbols and parameters	

σ_o, E as defined in 3.2.1

l = unsupported length of member, in metres

K = effective length factor to be generally taken as unity but will be specially considered in association with end conditions

l_e = Kl = unsupported effective length of member, in metres

r = least radius of gyration of member cross-section, in mm, and may be taken as:

$$r = 10 \sqrt{\frac{I}{A}} \text{ mm}$$

A = cross-sectional area of member, in cm^2

I = least moment of inertia of member cross-section, in cm^4

λ = slenderness ratio and may be taken as:

$$\lambda = \frac{1000 l_e}{r}$$

$$\eta = \frac{2\pi^2 E}{\sigma_o}$$

Table 5.4.2 Factors of safety for overall member buckling

Condition	Factor of safety, F_C
(1) For case (a) as defined in 2.1.1:	
(a) When $\lambda < \sqrt{\eta}$	$1{,}67 + \dfrac{0{,}25\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,92
(2) For cases (b) and (c) as defined in 2.1.1:	
(a) When $\lambda < \sqrt{\eta}$	$1{,}25 + \dfrac{0{,}19\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,44
(3) For case (d) as defined in 2.1.1:	
(a) When $\lambda < \sqrt{\eta}$	$1{,}0 + \dfrac{0{,}15\lambda}{\sqrt{\eta}}$
(b) When $\lambda \geq \sqrt{\eta}$	1,15
Symbols and parameters	

F_C as defined in 4.2.1

λ and η as defined in Table 5.4.1

4.4.2 The local buckling of cylindrical shells, either unstiffened or ring-stiffened, is to be investigated if the proportions of the shell conform to the following:

$$\frac{D}{t} > \frac{E}{9\sigma_o}$$

4.4.3 When individual primary structural members are subjected to axial compression or combined axial compression and bending, the computed design stresses are to satisfy the following requirement:

$$\frac{\sigma_A}{\sigma_{PA}} + \frac{\sigma_B}{\sigma_{PB}} \leq 1{,}0$$

■ *Section 5* Fatigue design

5.1 General

5.1.1 Fatigue damage due to cyclic loading is to be considered in the design of all unit types. The extent of the fatigue analysis will be dependent on the mode and area of operation.

5.1.2 Where any unit is intended to operate at one location for an extended period of time, a rigorous fatigue analysis is to be performed using the long-term prediction of environment for that area of operation with the unit at the intended orientation. Due allowance is to be made of any previous operational history of the unit.

5.1.3 The two basic methods of fatigue analysis available are Deterministic Fatigue Analysis and Spectral Fatigue Analysis. Both are acceptable to LR.

5.1.4 Factors which influence fatigue endurance and should be accounted for in the design calculations include:

- Loading spectrum.
- Detail structural design.
- Fabrication and tolerances.
- Corrosion.
- Dynamic amplification.

5.1.5 The following important sources of cyclic loading should be considered in the design:

- Waves (including those which cause slamming and variable-buoyancy effects).
- Wind (especially when vortex shedding is induced, e.g., on slender members).
- Currents (where these influence the forces generated by waves and/or induced vortex shedding).
- Mechanical vibration (e.g., caused by operation of machinery).

5.1.6 Where a fine mesh finite element analysis is carried out to determine local geometric stress concentration factors, selection of associated S-N curves will be specially considered. Account is to be taken of fatigue stress direction relative to the weld. In general, the element mesh size adjacent to the weld detail under consideration is to be of the order of the local plate thickness. Mesh arrangement and analysis methodology are to be agreed with LR.

5.1.7 In general, stresses are to be determined using net scantlings, i.e., no corrosion allowance included, *see also* Pt 3, Ch 1,5.

5.2 Fatigue life assessment

5.2.1 Fatigue life assessment of all relevant structural elements is required to demonstrate that structural connections have a fatigue endurance consistent with the planned life of the unit and compliance with the minimum requirements. The following structural elements are to be included:

(a) Column-stabilised and tension-leg units:
- Bracing structure.
- Bracing connections to lower hulls, columns and decks.
- Column connections to lower hulls.
- Column connections to deck.
- Mooring structure and associated hull structure integration.
- General structural discontinuities.

(b) Surface type units:
- Hull longitudinal stiffener connections to transverse frames and bulkheads.
- Toe area of main structural brackets.
- Hopper knuckle connections.
- Main openings in the hull envelope.
- Mooring structure and associated hull structure integration.
- General structural discontinuities in the primary hull structure.

(c) Self-elevating units:
- Lattice legs and connections to footings.
- Leg support structure.
- Raw water towers.

(d) Other unit types:
- Special consideration will be given to the hull structure of other unit types on the basis of this Section.

(e) General: Hull, deck and supporting structure in way of topside facilities, e.g:
- Module support.
- Process plant support stools.
- Crane pedestal.
- Flare structures.
- Offloading station.
- Drilling derrick and substructures.

(f) General: Other structures subjected to significant cyclic loading.

5.2.2 Fatigue life is normally governed by the fatigue behaviour of welded joints, including both main and attachment welds. Structure is to be detailed and constructed to ensure that stress concentrations are kept to a minimum and that, where possible, components may deform without introducing secondary effects due to local restraints.

5.2.3 The minimum design fatigue life of a unit is to be specified by the Owner, but is not to be less than 25 years, unless agreed otherwise by LR. *See also* Part 10 for ship units.

5.3 Fatigue damage calculations

5.3.1 The fatigue damage calculations are to be based on the long-term distribution of the applied stress ranges. A sufficient number of draughts and directions are to be included.

5.3.2 An appropriate wave spectrum is to be used and representative percentages of the total cumulative spectrum included for each direction under consideration. When using a limited number of directions, account is to be taken of symmetry within the structure.

5.3.3 Cumulative damage may be calculated by Miner's summation:

$$\sum_{i=1}^{s} \left[\frac{n_i}{N_i}\right] \leq \frac{1,0}{F_s}$$

where
- s = number of stress range blocks
- n_i = actual number of cycles for stress range block number 'i'
- N_i = corresponding number of cycles obtained from the relevant S-N curve for the detail under consideration
- F_s = fatigue factor of safety from Table 5.5.1 or Table 5.5.2.

5.3.4 Cumulative damage for individual components is to take into account the degree of redundancy, accessibility of the structure and also the consequence of failure.

5.3.5 Fatigue life estimation is normally to be based on the Miner's summation method given in 5.3.3, but consideration will be given to the use of an appropriate fracture mechanics assessment.

5.4 Joint classifications and S-N curves

5.4.1 Acceptable joint classification and S-N curves for structural details are contained in Appendix A.

5.4.2 Consideration will be given to the use of alternative methods; detailed proposals are to be submitted and agreed with LR.

Table 5.5.1 Fatigue life factors of safety for structural components

Inspectable/repairable	Fatigue life factor	
	Consequence of failure	
	Non-substantial	Substantial *See* Note 1
Yes, dry *See* Note 2	1	2
Yes, wet *See* Note 3	2	4
No	3	10

NOTES
1. Substantial consequences of failure include, *inter alia*, loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking. In assessing consequences, account should be taken of the potential for progressive failure. This factor will be applicable for bottom structure of oil storage tanks of single bottomed units and side structures of oil storage tanks of single sided units.
2. Includes internal and external structural elements and connections which can be subjected to dry inspection and repair.
3. Includes external structural elements and connections situated below the minimum operating draught of the unit or structure which can only be inspected during in-water surveys but dry repairs could be carried out subject to special arrangements being provided.

Table 5.5.2 Fatigue life factors of safety for anchor line and tether components

Inspectable/replaceable	Fatigue life factor
Yes, dry	3
Yes, wet	5
No	10

NOTE
Anchor line or tether components include chains, steel wire ropes, and associated fittings such as shackles, connecting links, rope sockets and terminations.

5.4.3 Full penetration welds are normally to be used for all nodal joints (i.e., tubular brace to chord connections). For full penetration welded joints, fatigue cracking would usually be located at the weld toe. However, if partial penetration welds have to be used where weld throat failure is a possibility, fatigue should be assessed using the 'W' curve and a shear stress estimated at the weld root.

5.4.4 For nodal joints, the stress range to be used in the fatigue analysis is the hot spot stress range at the weld toe. For any particular type of loading (e.g., axial loading) this stress range is the product of the nominal stress range in the brace and the appropriate stress concentration factor (SCF).

5.4.5 The hot spot stress is defined as the greatest value around the brace/chord intersection of the extrapolation to the weld toe of the geometric stress distribution near the weld toe. This hot spot stress incorporates the effects of overall joint geometry (i.e., the relative sizes of brace and chord) but omits the stress-concentrating influence of the weld itself which results in a local stress distribution. Hence, the hot spot stress is considerably lower than the peak stress but provides a consistent definition of stress range for the design S-N curve (curve 'T' shown in Appendix A). Stress ranges both for the brace and chord sides are to be considered in any fatigue assessment.

5.4.6 For all other types of joint (e.g., welded stiffeners or attachments, including those at nodal joints) the joint classifications and corresponding S-N curves are to take into account the local stress concentrations created by the joints themselves and by the weld profile. The relevant stress range is then the nominal stress range which is to include any local bending adjacent to the weld under consideration. However, if the joint is also situated in a region of stress concentration resulting from the gross shape of the structure, this is to be taken into account.

5.4.7 In load-carrying partial penetration or fillet-welded joints, where cracking could occur in the weld throat, the relevant stress range is the maximum range of shear stress in the weld metal. For details which are particularly fatigue-sensitive, where failure could occur through the weld, full penetration welding is normally to be used.

5.4.8 Geometric stress concentrations may be determined from experimental tests, appropriate references, semi-empirical or parametric formulae or analytical methods (e.g., finite elements analysis). *See also* Appendix A.

5.4.9 Normal fabrication tolerances according to good workmanship standards as given by the Rules are considered to be implicitly accounted for in the S-N curves.

5.5 Cast or forged steel

5.5.1 Fatigue life calculations for cast or forged steel structural components are to include details of the fatigue endurance curve for the material, taking account of the particular environment, mean stress and the existence of casting defects, and the derivation of any stress concentration factors.

5.6 Factors of safety on fatigue life

5.6.1 The minimum factors of safety on the calculated fatigue life of structural components are to be in accordance with Table 5.5.1. For mooring systems, *see* 5.6.2.

5.6.2 The minimum factors of safety on the calculated fatigue life of anchor lines and tether components of mooring systems are to be in accordance with Table 5.5.2.

■ *Section 1* General requirements

1.1 General

1.1.1 All parts of the structure are to be designed to withstand the most severe combination of overall and local loadings to which they may be subjected. Permissible stresses for direct calculation methods are to comply with the requirements of Chapter 5.

1.1.2 The local effects of the loadings listed in Ch 3,4 are to be considered and all parts of the structure are to be examined individually as necessary, and the calculations submitted. The minimum Rule scantlings of all structures are also to comply with the requirements of this Chapter, as applicable.

1.1.3 The design heads for local strength of column-stabilised, sea bed-stabilised and self-elevating units are to be in accordance with Section 2.

1.1.4 The local strength of ship units is to comply with Part 10. The lcoal strength of other surface type units is to comply with Ch 4,4.

1.1.5 The scantlings of machinery seatings are to be specially considered. On self-propelled units, full details of power, and RPM, etc., are to be submitted.

1.1.6 The connections to anchor points as defined in Pt 3, Ch 10,10 and the structure in way of fairleads, chainstoppers, winches, etc., forming part of anchoring or positional mooring systems are to be designed for a working load equal to the breaking strength of the mooring or anchoring lines as applicable, *see also* Pt 3, Ch 10,11. Permissible stresses are to be in accordance with Ch 5,2.1.1(c). Special consideration will be given to grouped line redundant positional mooring systems.

1.1.7 Supply boat moorings and supporting structure are to be designed for a working load equal to the breaking strength of the mooring line. Permissible stresses are to be in accordance with Ch 5,2.1.1(c).

1.1.8 Towing brackets and supporting structure are to be designed for a working load equal to the breaking strength of the towline in accordance with the requirements of Chapter 9.

1.1.9 The supporting structure in way of lifeboat davits is to be designed for the dynamic factors defined in Ch 4,1.9 and the permissible stress levels are to comply with loadcase (a) in Ch 5,2.1.1.

1.1.10 The supporting structure to turret bearings on ship units is to comply with Part 10.

1.1.11 The scantlings of product swivels are to be determined in accordance with Pt 3, Ch 13,6 and the supporting structure is to be integrated into the unit's hull structure and the local permissible stresses are to comply with Chapter 5.

1.1.12 The supporting structures to production and process plant are to comply with Pt 3, Ch 8.

1.1.13 When a **DRILL** notation is to be assigned, the scantlings of the drilling derrick are to be determined in accordance with Pt 3, Ch 7. The supporting sub-structure is a classification item and calculations are to be submitted in accordance with Pt 3, Ch 7. The sub-structure is to be integrated into the unit's hull structure and the local permissible stresses are to comply with Chapter 5.

■ *Section 2* Design heads

2.1 General

2.1.1 This Section contains the local design heads and pressures to be used in the derivation of scantlings for decks, and bulkheads. Where scantlings in excess of Rule requirements are fitted the procedure to be adopted to determine the permissible head/pressure is also given.

2.2 Symbols

2.2.1 The symbols used in this Section are defined as follows:

L and *D* as defined in Ch 1,5

h_i = appropriate design head, in metres

p = design loading, in kN/m^2 (tonne-f/m^2)

p_a = applied loading, in kN/m^2 (tonne-f/m^2)

C = stowage rate, in m^3/tonne, *see* 2.3

$= \dfrac{h_i}{p}$

E = correction factor for height of platform

$= \dfrac{0{,}0914 + 0{,}003L}{D - T} - 0{,}15$, but not less than zero nor more than 0,147

T = T_0 or T_T as defined in Ch 1,5 as appropriate.

2.3 Stowage rate and design heads

2.3.1 The following standard stowage rates are to be used:

(a) 1,39 m^3/tonne for weather or general loading on decks.

(b) 0,975 m^3/tonne for tanks with liquid of density 1,025 tonne/m^3 or less on tank bulkheads and for watertight bulkheads. For liquid of density greater than 1,025 tonne/m^3, the corresponding stowage rates are to be adopted.

2.3.2 The design heads and permissible deck loading are shown in Table 6.2.1. For helicopter landing areas, *see* Section 5.

Table 6.2.1 Design heads and permissible deck loadings (SI units) (*conclusion*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN/m^2	Equivalent design head h_i in metres	Permissible deck loading in kN/m^2	Equivalent permissible head, in metres
1. Weather decks	—	—	—	h_1	—	—
(a) Loading for minimum scantlings						
(i) Exposed deck	All structure	1,39	9,0 + 14,41E	1,28 + 2,04E	9,0	1,28
(b) Specified deck loading						
(i) Exposed deck	All structure	1,39	p_a + 14,41E but not less than (a) above	0,14p_a + 2,04E	p_a	0,14p_a
2. Other decks						
(a) Loading for minimum scantlings						
(i) Work areas	All structure	1,39	9,0	h_2 1,28	—	—
(ii) Storage areas	All structure	1,39	14,13	h_3 2,0	—	—
(iii) Decks forming crown of deep tanks	All structure	C	$\frac{9,82h}{C}$ (*see* Note 2)	h_4 h (*see* Note 2)	—	—
(iv) Accommodation decks	All structure	1,39	8,5	h_5 1,2	—	—
(b) Specified deck loading						
(i) All areas	All structure	1,39	p_a + 14,41E but not less than (a) above	h_2, h_3, h_5 0,14p_a	—	—
(c) Superstructure decks (*see* Note 3)				h_6		
(i) 1st tier	All structure	—	—	0,9 (*see* Note 4)	—	—
(ii) 2nd tier				0,6		
(iii) 3rd tier and above				0,45		
(d) Walkways and access areas	All structure	1,39	4,5	h_7 0,64	—	—

Table 6.2.1 Design heads and permissible deck loadings (SI units) (*conclusion*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in kN-f/m^2	Equivalent design head h_i in metres		Permissible deck loading in kN-f/m^2	Equivalent permissible head, in metres
3. Watertight bulkheads	All structure	0,975	$10{,}07h_4$	h_4	*see* Table 6.7.1	—	—
4. Deep tank bulkheads	All structure	C but ≤ 0,975	$\dfrac{9{,}82h_4}{C}$	h_4	*see* Table 6.7.1	—	—

NOTES
1. The equivalent design head is to be used in conjunction with the appropriate formulae in the Rules.
2. Where h equals half the distance to the top of the overflow above crown of tank.
3. For forecastle decks forward of 0,12L from F.P., *see* weather decks.
4. Where the deck is exposed to the weather add 2,04E to the design head.

Table 6.2.1 Design heads and permissible deck loadings (metric units) (*see continuation*)

Structural item and position	Component	Standard stowage rate C, in m^3/tonne	Design loading p, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible deck loading in tonne-f/m^2	Equivalent permissible head, in metres
1. Weather decks	—	—	—	h_1	—	—
(a) Loading for minimum scantlings						
(i) Exposed deck	All structure	1,39	0,92 + 1,467E	1,28 + 2,04E	0,92	1,28
(b) Specified deck loading						
(i) Exposed deck	All structure	1,39	p_a + 1,467E but not less than (a) above	1,4p_a + 2,04E	p_a	1,4p_a
2. Other decks						
(a) Loading for minimum scantlings						
(i) Work areas	All structure	1,39	0,92	h_2 1,28	—	—
(ii) Storage areas	All structure	1,39	1,44	h_3 2,0	—	—
(iii) Decks forming crown of deep tanks	All structure	C	$\frac{h}{C}$ (*see* Note 2)	h_4 h (*see* Note 2)	—	—
(iv) Accommodation decks	All structure	1,39	0,865	h_5 1,2	—	—
(b) Specified deck loading						
(i) All areas	All structure	1,39	p_a + 1,467E but not less than (a) above	h_2, h_3, h_5 0,14p_a	—	—
(c) Superstructure decks (*see* Note 3)				h_6		
(i) 1st tier	All structure	—	—	0,9 (*see* Note 4)	—	—
(ii) 2nd tier				0,6		
(iii) 3rd tier and above				0,45		

Table 6.2.1 Design heads and permissible deck loadings (metric units) *(conclusion)*

Structural item and position	Component	Standard stowage rate *C*, in m^3/tonne	Design loading *p*, in tonne-f/m^2	Equivalent design head h_i in metres	Permissible deck loading in tonne-f/m^2	Equivalent permissible head, in metres
(d) Walkways and access areas	All structure	1,39	0,46	h_7 0,64	—	—
3. Watertight bulkheads	All structure	0,975	$\frac{h_4}{0,975}$	h_4 see Table 6.7.1	—	—
4. Deep tank bulkheads	All structure	*C* but ≤ 0,975	$\frac{h_4}{C}$	h_4 see Table 6.7.1	—	—

NOTES
1. The equivalent design head is to be used in conjunction with the appropriate formulae in the Rules.
2. Where *h* equals half the distance to the top of the overflow above crown of tank.
3. For forecastle decks forward of 0,12*L* from F.P., see weather decks.
4. Where the deck is exposed to the weather add 2,04*E* to the design head.

Section 3
Watertight shell boundaries

■ *Section 3* Watertight shell boundaries

3.1 General

3.1.1 The requirements of Chapter 7 regarding watertight integrity are to be complied with.

3.1.2 The minimum requirements for watertight shell plating and framing of column-stabilised units, self-elevating units, tension-leg units, buoys and deep draught caissons are given in this Section.

3.1.3 The minimum requirements for watertight shell plating and framing of surface type units are to comply with:
- Part 10 for ship units; and
- Ch 4,4 for other surface type units.

3.1.4 The Rules are, in general, applicable to shell plating with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed, the scantlings are to be specially considered and the minimum shell thickness is to satisfy the buckling strength requirements given in Chapter 5, but the minimum requirements of this Section are to be complied with.

3.1.5 The shell plating thickness is to satisfy the requirements for the overall strength of the unit in accordance with:
- Part 10 for ship units; and
- Chapters 4 and 5 for other unit types.

3.1.6 The scantlings of moonpool bulkheads will be specially considered with regard to the maximum forces imposed on the structure and the permissible stress levels are to comply with Chapter 5.

3.1.7 The minimum scantlings of moonpool bulkheads on buoys and deep draught caissons are to comply with 3.4 and the load head h_o in Table 6.3.5 is to be measured to the top of the moonpool bulkhead.

3.1.8 The minimum scantlings of moonpools and drilling well bulkheads on column-stabilised and tension-leg units are to comply with 3.2.5, but plating thickness is to be not less than 9,0 mm, *see also* Pt 3, Ch 13,2.

3.1.9 The scantlings of moonpools and drilling well bulkheads on surface type units and self-elevating units are to comply with Pt 3, Ch 13,2.

3.1.10 The scantlings of circumturret well bulkheads on ship units are to comply with Part 10.

3.1.11 Where column structures or superstructures extend over the side shell of the unit, the side shell/sheerstrake is to be suitably increased locally at the ends of the structure.

3.1.12 On units fitted with two chines each side the bilge plating should not be less than required for bottom plating. When units are fitted with hard chines the shell plating is not to be flanged, but where the chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than 10 times the plate thickness. Where a solid round chine bar is fitted, the bar diameter is to be not less than three times the thickness of the thickest abutting plate. Where welded chines are used, the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld, *see also* Table 6.3.3.

3.1.13 The plating of swim ends is to have a thickness not less than that required for bottom shell plating.

3.1.14 Where a rounded sheerstrake is adopted, the radius should, in general, be not less than 15 times the plate thickness.

3.1.15 Sea inlets, or other openings, are to have well rounded corners and, so far as possible, are to be kept clear of the bilge radius. Openings on, or near to, the bilge radius are to be elliptical. The thickness of sea inlet box plating is to be the same as the adjacent shell, but not less than 12,5 mm. The ends of stiffeners should in general be bracketed and alternative proposals may be considered.

3.1.16 In general, secondary hull framing is to be continuous and the end connections of stiffeners to watertight bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of strength.

3.1.17 The end connections of secondary hull framing and primary members are to comply with:

- Pt 10, Ch 3,1 for ship units; and
- Chapter 8 for other unit types.

3.1.18 The lateral and torsional stability of stiffeners together with web and flange buckling criteria are to be verified in accordance with Ch 5,3.

3.1.19 Web frames supporting secondary hull framing are, in general, to be spaced not more than 3,8 m apart when the length, L, is less than 100 m and (0,006L + 3,2) m apart where L is greater than 100 m. For units which are also required to operate aground, *see* Ch 4,2.

3.2 Column-stabilised and tension-leg units

3.2.1 When the external watertight boundaries of columns, lower hulls and footings are designed with stiffened plating, the minimum scantlings for shell plating, hull framing and web frames, etc., are to comply with Table 6.3.1, *see also* 3.2.3.

3.2.2 The scantlings determined from Table 6.3.1 are the minimum requirements for hydrostatic pressure loads only and the overall strength is to comply with Chapter 4.

3.2.3 Where cross ties are fitted in columns or lower hulls, the scantlings are to comply with 3.3.5 and 3.3.6 taking the head h_c as the pressure head h_o in accordance with Table 6.3.1 as appropriate. Where cross ties are fitted inside tanks, the requirements of 3.3.4 are also to be complied with.

3.2.4 When the scantlings of primary web frames or girders are determined by a frame analysis or where the boundaries of columns, lower hulls and footings are designed as shells either unstiffened or ring stiffened, the scantlings may be determined on the basis of an agreed analysis, *see* Ch 1,2. The minimum design loads are to be in accordance with Chapter 3 and the permissible stresses are to comply with Chapter 5. The scantlings are not to be less than required by 3.2.1.

3.2.5 The minimum scantlings of the external watertight boundaries of the upper hull structure are to comply with Table 6.3.2.

3.2.6 The shell plating and structure are to be reinforced in way of mooring fairleads, supply boat moorings, towing brackets and other attachments, *see also* Section 1.

3.2.7 Columns, lower hulls, footings and other areas likely to be damaged by anchors, chain cables and wire ropes, etc., are to be protected or suitably strengthened.

3.2.8 Openings are not permitted in the shell boundaries of columns, lower hulls and footings except when they are closed with watertight covers fitted with closely spaced bolts, *see* Chapter 7.

3.3 Self-elevating units

3.3.1 The minimum scantlings of shell plating are to comply with Table 6.3.3 and the secondary hull framing and primary members are to comply with Table 6.3.4, *see also* 3.3.4.

3.3.2 The shell plating thickness is to be suitably increased in way of high shear forces in way of drilling cantilevers and other concentrated loads.

3.3.3 The scantlings and arrangements of the boundary bulkheads of leg wells will be specially considered with regard to the maximum forces imposed on the structure, and the permissible stress levels are to comply with Chapter 5. The minimum scantlings are to comply with Table 6.7.1 as a tank bulkhead with the load head h_4 measured to the upper deck at side. In no case is the minimum plating thickness to be less than 9 mm.

3.3.4 When cross ties are fitted inside pre-load tanks, the tensile stress in the cross ties and its end connections is not to exceed 108 N/mm^2 (11,0 kgf/mm^2) at the test head, but the scantlings are also to comply with the requirements of 3.3.5 and 3.3.6.

Table 6.3.1 Watertight shell boundaries for lower hulls and columns of column-stabilised units and tension-leg units

Items and requirement	Boundaries of lower hull or columns
(1) Shell plating thickness *See also* 3.1.5	$t = 0{,}004 s f \sqrt{h_o k} + 2{,}5$ mm but not less than 9,0 mm
(2) Hull framing: (a) Modulus (b) Inertia	$Z = 8{,}5 s\, k\, h_o\, l_e^2 \times 10^{-3}$ cm^3 $I = \frac{2{,}3}{k} l_e Z$ cm^4
(3) Primary members: Web frames supporting framing: (a) Modulus (b) Inertia	$Z = 8{,}5 k\, h_o\, S\, l_e^2$ cm^3 $I = \frac{2{,}3}{k} l_e Z$ cm^4

Symbols

f = $1{,}1 - \frac{s}{2500S}$ but not to be taken greater than 1,0

h_o = load head in metres measured vertically as follows:
(a) For shell plating the distance from a point one-third of the height of the plate above its lower edge to a point $1{,}4T_0$ above the keel or to the bottom of the upper hull structure whichever is the lesser with a minimum of 6,0 m.
(b) For hull framing and primary members, the distance from the middle of the effective length to a point $1{,}4T_0$ above the keel or to the bottom of the upper hull structure whichever is the lesser with a minimum of 6,0 m.

k = steel factor as defined in Ch 2,1

l_e = effective length of member, in metres, as defined in Ch 3,3.3

s = spacing of frames, in mm

S = spacing or mean spacing of primary members, in metres

T_0 = maximum operating draught, in metres, as defined in Ch 1,5

NOTES
1. In no case are the scantlings in way of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using the load head h_4.
2. In no case are the scantlings to be less than the requirements given in Table 6.7.1 for watertight bulkheads using the load head h_4.
3. Where frames are not continuous they are to be fitted with end brackets in accordance with Section 7 or equivalent arrangements provided.

3.3.5 When cross ties are fitted to support shell web frames the scantlings of the web frames are to be determined from Tables 6.3.4 and 6.7.1 and the area and least moment of inertia of the cross tie are to satisfy the following, *see also* 3.3.6 and 3.3.7:

$$A_c \geq \frac{0{,}82 b_c\, h_c\, S\, k}{1 - 0{,}42\left(\frac{l_c}{r\sqrt{k}}\right)}$$

where

b_c = one half the vertical distance in metres between the centres of the bottom or deck webs adjacent to the cross tie, *see* Fig. 6.3.1

h_c = vertical distance from the centre of the cross tie to deck, in metres, *see* Fig. 6.3.1

l_c = length of cross tie between the toes of the horizontal brackets on the web frames at the cross tie, in metres

S = spacing of web frames, in metres

l_e = span of web frames, *see* Fig. 6.3.1

I_c = least inertia of cross tie cross-section, in cm^4

A_c = area of cross tie, in cm^2

r = least radius of gyration of cross tie cross-section, in cm

$= \sqrt{\frac{I_c}{A_c}}$

b_e as defined in Ch 3,3.3.

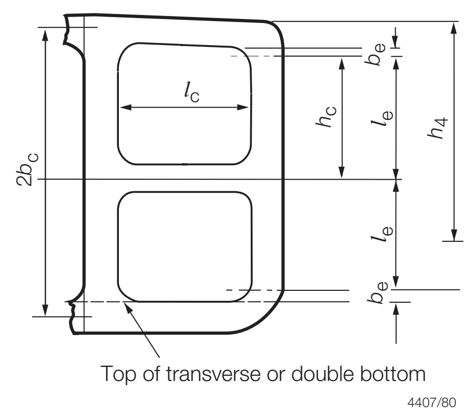


Fig. 6.3.1 Cross tie construction

Table 6.3.2 Watertight shell boundaries of the upper hull of column-stabilised units and tension-leg units

Items and requirement	Boundaries of upper hull
(1) Shell plating thickness general *See also* 3.1.5	The greater of the following: (a) $t = 0{,}004sf\sqrt{h_4 k}$ mm (b) $t = 0{,}012s_1\sqrt{k}$ but not less than 7,5 mm
(2) Bottom plating thickness between columns within $\frac{W}{2}$ outside of column shell but not less than two web frame spaces *See also* 3.1.5	The greater of the following: (a) $t = 0{,}004s\,f\sqrt{h_4 k} + 2{,}5$ mm (b) $t = 0{,}012s_1\sqrt{k}$ but not less than 7,5 mm
(3) Shell stiffeners and primary webs, general	To comply with Table 6.7.1 using the load head h_4
(4) Shell stiffeners adjacent to columns as defined in (2): (a) Modulus (b) Inertia	 $Z = 8{,}5s\,k\,h_4\,l_e^2 \times 10^{-3}$ cm^3 $I = \frac{2{,}3}{k}\,l_e\,Z$ cm^4
Symbols	
Symbols as defined in Table 6.7.1, except as follows: h_4 = load head, in metres, as defined in Table 6.7.1 for watertight bulkheads but not less than 6,0 m $s_b = 470 + \frac{L}{0{,}6}$ mm or 700, whichever is the smaller s_1 = s but is not to be taken less than s_b W = greatest width or diameter of stability column, in metres	
NOTE In no case are the scantlings in way of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using the load head h_4.	

3.3.6 The scantlings of the webs and flanges of cross ties are to be checked for buckling by direct calculation.

3.3.7 Design of end connections of cross ties is to be such that the area of the welding, including vertical brackets, where fitted, is to be not less than the minimum cross sectional area of the cross tie derived from 3.3.5. To achieve this, full penetration welds may be required and thickness of brackets may require further consideration. Attention is to be given to the full continuity of area of the backing structure on the transverses. Particular attention is also to be paid to the welding at the toes of all end brackets on the cross tie.

3.4 Buoys and deep draught caissons

3.4.1 Where the external watertight hull boundaries are designed with stiffened plating, the minimum scantlings for shell plating, hull framing and web frames supporting framing, etc., are to comply with Table 6.3.5.

3.4.2 The scantlings determined from Table 6.3.5 are the minimum requirements for hydrostatic pressure loads only and the overall strength is to comply with Chapter 4.

3.4.3 Where the scantlings of primary web frames are determined by a frame analysis or where the boundaries are designed as shells, either unstiffened or ring stiffened, the scantlings are to be determined on the basis of an established analysis using the appropriate design pressure heads as defined in Chapter 3. The permissible stresses are to comply with Chapter 5, but the scantlings are not to be less than required by 3.4.1.

3.4.4 The shell plating and hull framing are to be reinforced in way of mooring line attachments, mooring fairleads, supply boat moorings, towing brackets and other attachments, *see also* Section 1.

3.4.5 Areas of the hull which may be damaged by chain cables or wire ropes are to be protected or suitably strengthened.

3.4.6 Where cross ties are fitted to support shell web frames, the scantlings are to comply with 3.3.5 and 3.3.6 taking the head h_c as the pressure head h_o in accordance with Table 6.3.5.

3.4.7 Where cross ties are fitted inside tanks, the requirements of 3.3.4 are to be complied with.

Table 6.3.3 Shell plating self-elevating units

Location	Thickness, in mm, *see also* 3.1.5
(1) Bottom shell plating *See* Notes 1, 2 and 4	The greater of the following: (a) $t = 0{,}001s_1\,(0{,}043L + 10)\sqrt{\dfrac{1}{k}}$ (b) $t = 0{,}0052s_1\sqrt{1{,}5T_T\,k}$
(2) Bilge plating (framed) *See* Note 2	t as for (1)
(3) Side shell plating *See* Notes 1, 2, 3 and 4	(a) Above $\dfrac{D}{2}$ from base: The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L + 7)\sqrt{\dfrac{1}{k}}$ (ii) $t = 0{,}0042s_1\sqrt{1{,}4T_T\,k}$ (b) At upper turn of bilge (*see* Note 2): The greater of the following: (i) $t = 0{,}001s_1\,(0{,}059L + 7)\sqrt{\dfrac{1}{k}}$ (ii) $t = 0{,}0054s_1\sqrt{1{,}2T_T\,k}$ (c) Between upper turn of bilge and $\dfrac{D}{2}$ from base: The greater of the following: (i) t from (b)(i) (ii) t from interpolation between (a)(ii) and (b)(ii)
(4) Minimum plating	$t_m = (6{,}5 + 0{,}033L)\sqrt{\dfrac{ks_1}{s_b}}$
Symbols	
L, D, T_T, as defined in Ch 1,5 k = steel factor as defined in Ch 2,1 s = spacing of secondary stiffeners, in mm $s_b = 470 + \dfrac{L}{0{,}6}$ mm or 700 mm, whichever is the smaller $s_1 = s$, but is not to be taken less than s_b	
NOTES 1. In no case is the shell plating to be less than t_m. 2. When no bilge radius is fitted and the unit is fitted with hard chines, the bottom shell thickness required by (1) is, in general, to be extended up to $\dfrac{D}{4}$ from base, *see* 3.1.10. 3. The thickness of side shell need not exceed that determined from (1) for bottom shell when using the spacing of side shell stiffeners. 4. In no case are the scantlings of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using load head h_4.	

Table 6.3.4 Shell framing self-elevating units

Items and location	Modulus
(1) Hull framing, *see* Note 1 (a) Bottom frames (b) Side frames	 $Z = 11{,}0 s\, k\, h_T\, l_e^2 \times 10^{-3}$ cm^3 $Z = 8{,}0 s\, k\, h_T\, l_e^2 \times 10^{-3}$ cm^3
(2) Primary members, *see* Note 1 (a) Bottom web frames supporting framing (b) Side web frames supporting framing	 $Z = 11{,}0 k\, h_T\, S\, l_e^2 \times 10^{-3}$ cm^3 $Z = 8{,}0 k\, h_T\, S\, l_e^2 \times 10^{-3}$ cm^3
Symbols	
D and T_T as defined in Ch 1,5 h_T = load head, in metres, and is to be taken as the distance from the middle of the effective length to a point $1{,}6T_T$ above the keel or to the upper deck at side whichever is the lesser but not less than $0{,}01L + 0{,}7$ k = steel factor as defined in Ch 2,1 l_e = effective length of member, in metres, as defined in Ch 3,3.3 s = spacing of frames, in mm S = spacing or mean spacing of primary members, in metres	
NOTES 1. In no case are the scantlings in way of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using the load head h_4. 2. In no case are the scantlings to be less than the requirements given in Table 6.7.1 for watertight bulkheads using the load head h_4. 3. Where frames are not continuous they are to be fitted with end brackets in accordance with Section 7 or equivalent arrangements provided.	

Table 6.3.5 Watertight shell boundaries of buoys and deep draught caissons

Items and requirement	Shell boundaries, *see* Note 5
(1) Shell plating thickness *See also* 3.1.5	$t = 0{,}004sf\sqrt{h_o k} + 2{,}5$ mm but not less than 9,0 mm
(2) Hull framing: (a) Modulus (b) Inertia	 $Z = 8{,}5s\,k\,h_o\,l_e^2 \times 10^{-3}$ cm^3 $I = \frac{2{,}3}{k}\,l_e Z$ cm^4
(3) Primary members: Web frames supporting framing (a) Modulus (b) Inertia	 $Z = 8{,}5k\,h_o\,S\,l_e^2$ cm^3 $I = \frac{2{,}5}{k}\,l_e Z$ cm^4

Symbols

f = $1{,}1 - \frac{s}{2500S}$ but not to be taken greater than 1,0

h_o = load head in metres measured vertically as follows:
- (a) For shell plating the distance from a point one third of the height of the plate above its lower edge to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater with a minimum of 6,0 m, *see* Note 3
- (b) For hull framing and primary members, the distance from the middle of the effective length to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater, with a minimum of 6,0 m, *see* Note 3

k = steel factor as defined in Ch 2,1

l_e = effective length of member in metres as defined in Ch 3,3.3

s = spacing of frame in mm

S = spacing or mean spacing of primary members, in metres

NOTES
1. In no case are the scantlings in way of tanks to be less than the requirements given in Table 6.7.1 for tank bulkheads using the load head h_4.
2. In no case are the scantlings to be less than the requirements given in Table 6.7.1 for watertight bulkheads using the load head h_4.

3a. For shell plating of units defined in Pt 3, Ch 13 which are designed to follow the wave profile, h_o need not exceed the distance measured from a point one third of the height of the plate above its lower edge to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater. (But note that t shall not be less than 9,0 mm.)

3b. For hull framing of units defined in Pt 3, Ch 13 which are designed to follow the wave profile, h_o need not exceed the distance measured from the middle of the effective length to the top of the highest predicted wave in the most unfavourable design situation or to a height 1,0 m above the uppermost deck, whichever is the greater, but h_o shall not be less than the h_o calculated from the shell plating thickness formulation (Table 6.3.5 (1)) that corresponds to the minimum thickness requirement of 9,0 mm.

4. Where frames are not continuous they are to be fitted with end brackets in accordance with Section 7 or equivalent arrangements provided.
5. The scantlings of shell boundaries derived from this Table are to be suitably increased in way of tanks which cannot be inspected at normal periodic surveys, *see* Ch 4,7.10.

■ *Section 4* Decks

4.1 General

4.1.1 The design deck loadings for all unit types are not to be less than those defined in Sections 1 and 2.

4.1.2 The scantlings of deck structures are to comply with:
- Part 10 for ship units; and
- Ch 4,4 for other surface type units.

The requirements of 4.1.5 and 4.1.6 are also to be complied with as applicable.

4.1.3 The minimum scantlings of deck structures on column-stabilised units, self-elevating units, tension-leg units, buoys and deep draught caissons are to comply with this Section.

4.1.4 The scantlings of deck structures are also to satisfy the overall strength requirements in Chapter 4 and be sufficient to withstand the actual local loadings plus any additional loadings superimposed due to overall frame action. The permissible stress levels are to comply with Chapter 5.

4.1.5 Where decks form watertight boundaries in damage stability conditions, the minimum scantlings are not to be less than required for watertight bulkheads given in Section 7.

4.1.6 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment supporting structures to drilling derricks and flare structures, etc., are considered to be classification items regardless of whether or not the process/drilling plant facility is classed and the loadings are to be determined in accordance with Pt 3, Ch 8,2. Permissible stress levels are to comply with Chapter 5.

4.2 Deck plating

4.2.1 The requirements are in general applicable to strength/weather deck plating with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed, the scantlings will be specially considered, but the minimum requirements of Table 6.4.1 are to be complied with.

4.2.2 The minimum thickness of deck plating is to comply with the requirements of Table 6.4.1, except for decks in way of erections above the upper deck. For erection decks, *see* Section 6.

4.2.3 The thickness of strength/weather deck plating is also to be that necessary to satisfy the overall strength requirements of:

- Part 10 for ship units; and
- Chapters 4 and 5 for other unit types.

4.2.4 The deck plating thickness and supporting structure in way of towing brackets, winches, masts, crane pedestals, davits and machinery items, etc., is to be suitably reinforced, *see also* Section 1.

4.2.5 Where plated decks are sheathed with wood or approved compositions, consideration will be given to allowing a reduction in the minimum plating thickness given in Table 6.4.1.

4.3 Deck stiffening

4.3.1 The scantlings of deck stiffeners are to comply with the requirements of Table 6.4.2. Stiffeners fitted in way of concentrated loads and heavy machinery items, etc., will be specially considered.

4.3.2 The lateral and torsional stability of stiffeners together with web and flange buckling criteria are to be verified in accordance with Ch 5,3.

4.3.3 End connection of stiffeners to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of primary strength. In general deck stiffeners are to be continuous through primary support structure, including bulkheads but alternative arrangements will be considered. The end connections of stiffeners are in general to be in accordance with the requirements of Chapter 8.

Table 6.4.1 Deck plating

Symbols	Location	Thickness, in mm, *see also* 4.2.2
b = breadth of increased plating, in mm f = $1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0 k = steel factor as defined in 2.1.2 s = spacing of deck stiffeners, in mm s_1 = s but is to be taken not less than the smaller of: $470 + \dfrac{L}{0{,}6}$ mm or 700 mm A_f = cross sectional area of girder face plate, in cm^2 K_1 = 2,5 mm at bottom of tank = 3,5 mm at the crown of tank L = length of unit, in metres, as defined in Ch 1,5.1 S = spacing of primary members, in metres ρ, h_4 as defined in Table 6.7.1	(1) Strength/weather deck *See* Notes 1 and 2	The greater of the following: (a) $t = 0{,}001 s_1 (0{,}059L + 7)\sqrt{\dfrac{1}{k}}$ (b) $t = 0{,}00083 s_1 \sqrt{Lk} + 2{,}5$ but not less than (2)
	(2) Lower decks	$t = 0{,}012 s_1 \sqrt{k}$ but not less than 7,0 mm
	(3) Platform decks	$t = 0{,}01 s_1 \sqrt{k}$ but not less than 6,5 mm
	(4) In way of the crown or bottom of tanks	$t = 0{,}004 sf \sqrt{\dfrac{\rho\, k\, h_4}{1{,}025}} + K_1$ or as (1), (2) or (3) whichever is the greater but not less than 7,5 mm
	(5) Plating forming the upper flange of underdeck girders	$t = \sqrt{\dfrac{A_f}{1{,}8k}}$ but not less than required by (1), (2), (3) or (4) as appropriate to the location of the plating Minimum breadth, b = 760 mm

NOTES
1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of Chapter 5.
2. On column-stabilised units when the primary deck structure consists of box girders or equivalent structure and the deck plating is considered as secondary structure only the thickness of the plating will be specially considered but in no case is the thickness to be less than 6,5 mm.
3. Where the local deck loading exceeds 43,2 kN/m^2 (4,4 tonne-f/m^2) the thickness of plating will be specially considered.

4.4 Deck supporting structure

4.4.1 The minimum scantlings of girders and transverses supporting deck stiffeners are to comply with the requirements of Table 6.4.3.

4.4.2 Transverses supporting deck longitudinals are, in general, to be spaced not more than 3,8 m apart when the length, L, is 100 m or less, and $(0{,}006L + 3{,}2)$ m apart where L is greater than 100 m.

Table 6.4.2 Deck stiffeners

Symbols	Location	Modulus, in cm^3	Inertia, in cm^4
d_w = depth of stiffener, in mm, *see* Note 2 h_1 = weather head, in metres h_2 = work area head, in metres h_3 = storage head, in metres h_4 = tank head, in metres, as defined in Table 6.7.1 h_5 = accommodation head, in metres k = steel factor defined in Ch 2,1.2 l_e = span point, in metres as defined in Ch 3,3.3 but not less than 1,5 m s = spacing of stiffeners, in mm γ = 1,4 for rolled or built sections = 1,6 for flat bars ρ as defined in Table 6.7.1	(1) Weather decks	$Z = 5{,}5s\,k\,h_1\,l_e^2 \times 10^{-3}$	—
	(2) Work areas	$Z = 5{,}5s\,k\,h_2\,l_e^2 \times 10^{-3}$	—
	(3) Storage areas	$Z = 5{,}0s\,k\,h_3\,l_e^2 \times 10^{-3}$	—
	(4) Accommodation decks and crew spaces	$Z = 4{,}5s\,k\,h_5\,l_e^2 \times 10^{-3}$	—
	(5) In way of the crown or bottom of tanks	As (1), (2), (3) or (4) as applicable, or $\dfrac{0{,}0113\rho\,s\,k\,h_4\,l_e^2}{\gamma}$ whichever is the greater	$I = \dfrac{2{,}3}{k}\,l_e Z$

NOTES
1. The load heads h_1, h_2, h_3 and h_5 are to be determined from the maximum design uniform loadings and are not to be less than the minimum design load heads given in Table 6.2.1.
2. The web depth, d_w, of stiffeners is to be not less than 60 mm.

Table 6.4.3 Deck girders, transverses and deep beams

Location and arrangements	Modulus, in cm^3	Inertia, in cm^4
(1) Girders and transverses in way of dry spaces: (a) Supporting point loads	Z to be determined from calculations using stress $\dfrac{123{,}5}{k}$ N/mm^2 $\left(\dfrac{12{,}6}{k}\text{ kgf/mm}^2\right)$ and assuming fixed ends	$I = \dfrac{1{,}85}{k}\,l_e Z$
(b) Supporting a uniformly distributed load	$Z = 4{,}75k\,S\,H_g\,l_e^2$	
(2) Deep beams supporting deck girders in way of dry spaces: (a) Supporting point loads	Z to be determined from calculations using stress $\dfrac{123{,}5}{k}$ N/mm^2 $\left(\dfrac{12{,}6}{k}\text{ kgf/mm}^2\right)$ and assuming fixed ends	$I = \dfrac{2{,}3}{k}\,l_e Z$
(b) Supporting a uniformly distributed load	$Z = 4{,}75k\,S\,H_g\,l_e^2$	
(3) Girders and transverses in way of the crown or bottom of tanks	$Z = 11{,}7\rho\,k\,h_4\,S\,l_e^2$	$I = \dfrac{2{,}5}{k}\,l_e Z$

Symbols

h_4 = tank head, in metres, as defined in Table 6.7.1
k = steel factor as defined in Ch 2,1.2
l_e = span point, in metres, defined in Ch 3,3.3
H_g = weather head h_1 or work area head h_2 or storage head h_3 or accommodation head h_5, in metres, as defined in Table 6.2.1 whichever is applicable
S = spacing of primary members, in metres
ρ as defined in Table 6.7.1

4.4.3 The web thickness, stiffening arrangements and end connections of primary supporting members are to be in accordance with Chapter 8.

4.4.4 Where a girder is subject to concentrated loads, such as pillars out of line, the scantlings are to be suitably increased. Also, where concentrations of loading on one side of the girder may occur, the girder is to be adequately stiffened against torsion.

4.4.5 Pillars are to comply with the requirements of Table 6.4.4.

4.4.6 Pillars are to be fitted in the same vertical line wherever possible, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

Table 6.4.4 Pillars

Symbols	Parameter	Requirement
b = breadth of side of a hollow rectangular pillar or breadth of flange or web of a built or rolled section, in mm d_p = mean diameter of tubular pillars, in mm k = local scantling higher tensile steel factor, *see* Ch 2,1.2.1, but not less than 0,72 l = overall length of pillar, in metres l_e = effective length of pillar, in metres, and is taken as $0{,}80l$ r = least radius of gyration of pillar cross-section, in mm, and may be taken as: $r = 10\sqrt{\dfrac{I}{A_p}}$ mm A_p = cross-sectional area of pillar, in cm^2 H_g as defined in Table 7.4.3 I = least moment of inertia of cross-section, in cm^4 P = load, in kN (tonne-f), supported by the pillar and is to be taken as: $P = P_o + P_a$ but not less than 19,62 kN (2 tonne-f) P_a = load, in kN (tonne-f), from pillar or pillars above (zero if no pillars over) P_o = load, in kN (tonne-f), supported by pillar based on H_g	(1) Cross-sectional area of all types of pillar	$A_p = \dfrac{k\,P}{12{,}36 - 51{,}5\,\dfrac{l_e}{r\sqrt{k}}}$ cm^2 $\left(A_p = \dfrac{k\,P}{1{,}26 - 5{,}25\,\dfrac{l_e}{r\sqrt{k}}}\ \text{cm}^2\right)$ *See* Note
	(2) Minimum wall thickness of tubular pillars	The greatest of the following: (a) $t = \dfrac{P}{0{,}392d_p - 4{,}9l_e}$ mm $\left(t = \dfrac{P}{0{,}04d_p - 0{,}5l_e}\ \text{mm}\right)$ (b) $t = \dfrac{d_p}{40}$ mm (c) t = 5,5 mm where $L < 90$ m, or = 7,5 mm where $L \geq 90$ m
	(3) Minimum wall thickness of hollow rectangular pillars or web plate thickness of I or channel sections	The lesser of the following: (a) $t = \dfrac{b\,r}{600l_e}$ mm (b) $t = \dfrac{b}{55}$ mm but to be not less than t = 5,5 mm where $L < 90$ m, or = 7,5 mm where $L \geq 90$ m
	(4) Minimum thickness of flanges of angle or channel sections	The lesser of the following: (a) $t_f = \dfrac{b\,r}{200l_e}$ mm (b) $t_f = \dfrac{b}{18}$ mm
	(5) Minimum thickness of flanges of built or rolled I sections	The lesser of the following: (a) $t_f = \dfrac{br}{400l_e}$ mm (b) $t_f = \dfrac{b}{36}$ mm

NOTE

As a first approximation, A_p may be taken as $\dfrac{\sqrt{k}\,P}{9{,}32}$ $\left(\dfrac{\sqrt{k}\,P}{0{,}95}\right)$ and the radius of gyration estimated for a suitable section having this area.

If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximation is to be made.

4.4.7 Tubular and hollow square pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

4.4.8 Where pillars are not fitted directly above the intersection of bulkheads, equivalent arrangements are to be provided.

4.4.9 In double bottoms where pillars are not directly above the intersection of the plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in floors and girders below the heels of pillars.

4.4.10 Where pillars are fitted inside tanks or under watertight flats, the tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 (11,0 kgf/mm^2) at the test heads. In general, such pillars should be of built sections, and end brackets may be required.

4.4.11 Pillars or equivalent structures are to be fitted below deckhouses, machinery items, winches, etc., and elsewhere where considered necessary.

4.4.12 The thickness of primary longitudinal and transverse bulkheads supporting decks is to satisfy the requirements for the overall strength of the unit in accordance with:

- Part 10 for ship units; and
- Chapters 4 and 5 for other unit types.

When the bulkheads are to be watertight the scantlings are also to comply with the requirements of Section 7.

4.4.13 The lateral and torsional stability of primary bulkhead stiffeners together with web and flange buckling criteria are to be verified in accordance with Ch 5,3.

4.4.14 When openings are cut in the primary longitudinal and transverse bulkheads the openings are to have well rounded corners and full compensation is to be provided. All openings are to be adequately framed.

4.4.15 The minimum scantlings of non-watertight pillar bulkheads are to comply with the requirements of Table 6.4.5.

4.5 Deck openings

4.5.1 The corners of all deck openings are to be elliptical, parabolic or well rounded and the free edges are to be smooth. Large openings are to comply with 4.5.4 and 4.5.5.

4.5.2 All openings are to be adequately framed. Attention is to be paid to structural continuity, and abrupt changes of shape, section or plate thickness are to be avoided.

4.5.3 Arrangements in way of corners and openings are to be such as to minimise the creation of stress concentrations. Openings in highly stressed areas of decks, having a stress concentration factor in excess of 2,4, will require edge reinforcements in the form of a spigot of adequate dimensions, but alternative arrangements will be considered. The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation for the opening.

4.5.4 When large openings are cut in highly stressed areas of decks, the corners of the openings are to be elliptical, parabolic or rounded, with a radius generally not less than $^{1}/_{24}$ of the breadth of the opening. The minimum radius for large openings is to be 150 mm, provided the inner edge of the plating is stiffened by means of a coaming or spigot. Where the inner edge is unstiffened, the minimum radius is to be 300 mm.

4.5.5 Where the corners of large openings are rounded, the deck plating thickness is to be increased at the corners of the openings.

4.5.6 Compensation will be required for deck openings cut in highly stressed areas.

4.5.7 All openings which are required to be made watertight or weathertight are to have closing appliances in accordance with the requirements of Chapter 7.

Table 6.4.5 Non-watertight pillar bulkheads

Symbols	Parameter	Requirement
d_w, t_p, b, c as defined in Ch 3,3.2 r = radius of gyration, in mm, of stiffener and attached plating = $10\sqrt{\frac{I}{A}}$ mm for rolled, built or swedged stiffeners = $d_w\sqrt{\frac{3b+c}{12(b+c)}}$ mm for symmetrical corrugation s = spacing of stiffeners, in mm I = moment of inertia, in cm^4, of stiffener and attached plating A = cross-sectional area, in cm^2, of stiffener and attached plating $A_1 = \dfrac{P}{12,36 - 51,5\frac{l_e}{r}}$ cm^2 $\left(A_1 = \dfrac{P}{1,26 - 5,25\frac{l_e}{r}}\ cm^2\right)$ As a first approximation A_1 may be taken as $\dfrac{P}{9,32}$ $\left(\dfrac{P}{0,95}\right)$ $A_2 = \dfrac{P}{4,9 - 14,7\frac{l_e}{r}}$ cm^2 $\left(A_2 = \dfrac{P}{0,5 - 1,5\frac{l_e}{r}}\ cm^2\right)$ As a first approximation A_2 may be taken as $\dfrac{P}{3,92}$ $\left(\dfrac{P}{0,4}\right)$ P, l_e as defined in Table 6.4.4 $\lambda = \dfrac{b}{c}$	(1) Minimum thickness of bulkhead plating	5,5 mm
	(2) Maximum stiffener spacing	1500 mm
	(3) Minimum depth of stiffeners or corrugations	75 mm
	(4) Cross-sectional area (including plating) for rolled, built or swedged stiffeners supporting beams, longitudinals, girders or transverses	(a) Where $\frac{s}{t} \leq 80$ $A = A_1$ (b) When $\frac{s}{t} \geq 120$ $A = A_2$ (c) Where $80 < \frac{s}{t} < 120$ A is obtained by interpolation between A_1 and A_2
	(5) Cross-sectional area (including plating) for symmetrical corrugation	(a) Where $\frac{b}{t_p} \leq \frac{750\lambda\, l_e}{(\lambda + 0,25)\, r}$ $A = A_1$ (b) When $\frac{b}{t_p} > \frac{750\lambda\, l_e}{(\lambda + 0,25)\, r}$ $A = A_2$

■ *Section 5* Helicopter landing areas

5.1 General

5.1.1 This Section gives the requirements for decks intended for helicopter operations on all unit types.

5.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the unit. These include the 2009 IMO MODU Code and SOLAS Chapter II-2 Regulation 18 and Chapter III Regulation 28, as applicable. Guidance on the provision and operation of helicopter landing or winching facilities may be drawn from international Standards such as the *International Chamber of Shipping (ICS) Guide to Helicopter/Ship Operations* and the *International Aeronautical Search and Rescue Manual (IAMSAR)*.

5.1.3 Where helicopter decks are positioned so that they may be subjected to wave impacts, the scantlings are to be considered in a realistic manner and increased to the satisfaction of LR.

5.1.4 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.2 Plans and data

5.2.1 Plans and data are to be submitted giving the arrangements, scantlings and details of the helicopter deck. The type, size and weight of helicopters to be used are also to be indicated.

5.2.2 Relevant details of the largest helicopters, for which the deck is designed, are to be stated in the Operations Manual.

5.3 Arrangements

5.3.1 The landing area is to comply with applicable Regulations, International Standards or to the satisfaction of the National Authority, with respect to size, landing and take-off sectors of the helicopter, freedom from height obstructions, deck markings, safety nets and lighting, etc.

5.3.2 The landing area is to have an overall coating of non-slip material or other arrangements are to be provided to minimise the risk of personnel or helicopters sliding off the landing area.

5.3.3 A drainage system is to be provided in association with a perimeter guttering system or slightly raised kerb to prevent spilled fuel falling on to other parts of the unit. The drains are to be led to a safe area.

5.3.4 A sufficient number of tie-down points are to be provided to secure the helicopter.

5.3.5 Engine and boiler uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take-off or landing operations.

5.4 Landing area plating

5.4.1 The deck gross plate thickness, t, within the landing area is to be not less than:

$$t = t_1 + 1,5 \text{ mm}$$

where

$$t_1 = \frac{\alpha s}{1000\sqrt{k}} \text{ mm}$$

α = thickness coefficient obtained from Fig. 6.5.1

β = tyre print coefficient used in Fig. 6.5.1

$$= \log 10 \left(\frac{P_1 k^2}{s^2} \times 10^7 \right)$$

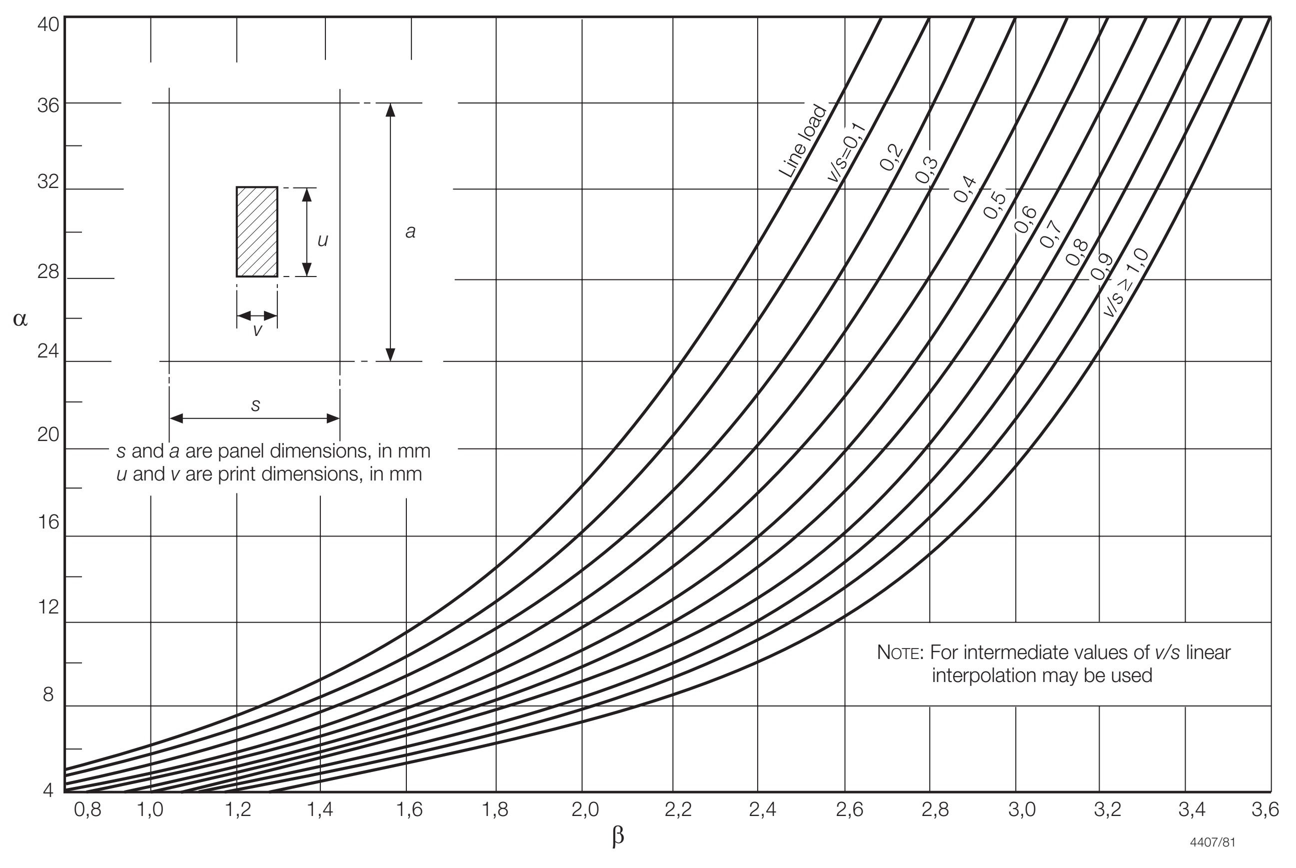


Fig. 6.5.1 Tyre print chart

The plating is to be designed for the emergency landing case taking:

$P_1 \ = 2{,}5\phi_1\, \phi_2\, \phi_3\, f\, \gamma\, P_w$ tonnes

where

ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 6.5.3

f = 1,15 for landing decks over manned spaces, e.g., deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes;

For helicopters with a single main rotor, P_w, is to be taken as P_h divided equally between the two main undercarriage wheels.

For helicopters with tandem main rotors, P_w, is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.

For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as 1/6 P_h for each of the two forward contact points and 1/3 P_h for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying Fig. 6.5.1.

γ = 0,6 generally. Factor to be specially considered where the helicopter deck contributed to the overall strength of the unit

Other symbols used in this Section are defined in Section 6 and in the appropriate sub-Section.

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown, it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plans.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from Fig. 6.5.1.

5.4.2 The plate thickness for aluminium decks is to be not less than:

$t \ = 1{,}4t_1 + 1{,}5$ mm

where

t_1 is the mild steel thickness as determined from 5.4.1.

Where the deck is fabricated using extruded sections with closely spaced stiffeners the plate thickness may be determined by direct calculations but the minimum deck thickness is to include 1,5 mm wear allowance. If the deck is protected by closely spaced grip/wear treads the wear allowance may be omitted.

5.5 Deck stiffening and supporting structure

5.5.1 The helicopter deck stiffening and the supporting structure for helicopter decks are to be designed for the load cases given in Table 6.5.1 in association with the permissible stresses given in Table 6.5.2. The helicopter is to be positioned so as to produce the most severe loading condition for each structural member under consideration.

5.5.2 In addition to the requirements of 5.5.1, the structure supporting helicopter decks is to be designed to withstand the loads imposed on the structure due to the motions of the unit. For self-elevating units, the motions are not to be less than those defined for transit conditions in Ch 4,3.10 and 3.11. The stress levels are to comply with load case 3 in Table 6.5.2, *see also* 5.1.3.

Table 6.5.1 Design load cases for deck stiffening and supporting structure

Load cases	Load			
	Landing area		Supporting structure *See* Note 1	
	UDL, in kN/m^2	Helicopter patch load *See* Note 2	Self-weight	Horizontal load *See* Note 2
(1) Overall distributed loading	2	—	—	—
(2) Helicopter emergency landing	0,5	$2{,}5P_w f$	W_h	$0{,}5P_h$
(3) Normal usage	0,5	$1{,}5P_w$	W_h	$0{,}5P_h + 0{,}5W_h$

Symbols

P_h, P_w and f as defined in 5.4.1

UDL = uniformly distributed vertical load over entire landing area

W_h = structural self-weight of helicopter platform

NOTES

1. For the design of the supporting structure for helicopter platforms applicable self-weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

Table 6.5.2 Permissible stresses for deck stiffening and supporting structure

<table>
<tr><td rowspan="3">Load case
See Table 6.5.1</td><td colspan="4">Permissible stresses, in N/mm^2</td></tr>
<tr><td>Deck secondary structure (beams, longitudinals, *See* Notes 1 and 2</td><td colspan="2">Primary structure (transverses, girders, pillars, trusses)</td><td>All structure</td></tr>
<tr><td colspan="2">Bending</td><td>Combined bending and axial</td><td>Shear</td></tr>
<tr><td>(1) Overall distributed loading</td><td>$\frac{147}{k}$</td><td>$\frac{147}{k}$</td><td>$0,6\sigma_c$</td><td rowspan="3">$\frac{\text{Bending}}{\sqrt{3}}$</td></tr>
<tr><td>(2) Helicopter emergency landing</td><td>$\frac{245}{k}$</td><td>$\frac{220,5}{k}$</td><td>$0,9\sigma_c$</td></tr>
<tr><td>(3) Normal usage</td><td>$\frac{176}{k}$</td><td>$\frac{147}{k}$</td><td>$0,6\sigma_c$</td></tr>
<tr><td colspan="5">Symbols</td></tr>
<tr><td colspan="5">k = a material factor:
= as defined in Ch 2,1.2 for steel members
= k_a as defined in Ch 2,1.3 for aluminium alloy members
σ_c = yield stress, 0,2% proof stress or critical compressive buckling stress, in N/mm^2, whichever is the lesser</td></tr>
<tr><td colspan="5">NOTES
1. Lower permissible stress levels may be required where helideck girders and stiffening contribute to the overall strength of the unit. Special consideration will be given to such cases.
2. When determining bending stresses in secondary structure, for compliance with the above permissible stresses, 100% end fixity may be assumed.</td></tr>
</table>

Table 6.5.3 Deck plate thickness calculation

<table>
<tr><td>Symbols</td><td colspan="2">Expression</td></tr>
<tr><td rowspan="3">a, s, u and v as defined in Fig. 6.5.1
P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 6.5.1 may be taken as the combined print
ϕ_1 = patch aspect ratio correction factor
ϕ_2 = panel aspect ratio correction factor
ϕ_3 = wide patch load factor</td><td>$\phi_1 = \dfrac{2v_1 + 1,1s}{u_1 + 1,1s}$</td><td>$v_1 = v$, but $\not> s$
$u_1 = u$, but $\not> a$</td></tr>
<tr><td>$\phi_2 = 1,0$
$= \dfrac{1}{1,3 - \dfrac{0,3}{s}(a-u)}$
$= 0,77\dfrac{a}{u}$</td><td>for $u \leq (a - s)$
for $a \geq u > (a - s)$
for $u > a$</td></tr>
<tr><td>$\phi_3 = 1,0$
$= 0,6\dfrac{s}{v} + 0,4$
$= 1,2\dfrac{s}{v}$</td><td>for $v < s$
for $1,5 > \dfrac{v}{s} > 1,0$
for $\dfrac{v}{s} \geq 1,5$</td></tr>
</table>

5.5.3 For load cases (1) and (2) in Table 6.5.1 the minimum moment of inertia, I, of aluminium alloy secondary structure stiffening is to be not less than:

$$I = \frac{5,25}{k_a} Z\, l_e \text{ cm}^4$$

where

Z is the required section modulus of the aluminium alloy stiffener and attached plating and k_a as defined in Ch 2,1.3.

5.5.4 Where a grillage arrangement is adopted for the platform stiffening, it is recommended that direct calculation procedures be used.

5.5.5 When the deck is constructed of extruded aluminium alloy sections, the scantlings will be specially considered on the basis of this Section.

5.6 Stowed helicopters

5.6.1 In addition to the requirements of 5.4 and 5.5, when arrangements are made to stow helicopters secured to the deck in predetermined positions, the structure is to be designed for the local loadings which can occur during normal operations.

5.6.2 Local loads on the structure are to be based on the maximum design undercarriage loadings specified by the helicopter manufacturer multiplied by a dynamic amplification factor based on the predicted motions of the unit as applicable. The self weight of the helicopter deck is to be included in the loadings imposed on the primary support structure. The permissible stress levels are to be in accordance with load case 3 in Table 6.5.2.

5.6.3 When the minimum design air temperature of the unit is 0°C or below, and considering the loadings in 5.6.2, the helicopter deck is to be assumed loaded with a uniformly distributed load of 0,5 kN/m^2 (0,05 tonne-f/m^2) to represent wet snow or ice.

5.7 Bimetallic connections

5.7.1 Where aluminium alloy platforms are connected to steel structures, details of the arrangements in way of the bimetallic connections are to be submitted.

■ *Section 6* Decks loaded by wheeled vehicles

6.1 General

6.1.1 Where it is proposed to use wheeled vehicles such as fork lift trucks and mobile cranes on deck structures, the deck plating and the supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service and the minimum gross scantlings are to comply with the requirements of Pt 3, Ch 9,3 of the Rules for Ships. In no case, however, are the scantlings to be less than would be required by the remaining requirements of this Chapter when the deck is considered as a weather deck or storage deck, as appropriate.

■ *Section 7* Bulkheads

7.1 General

7.1.1 This Section is applicable to watertight and deep tank transverse and longitudinal bulkheads, watertight flats, trunks and tunnels of all units except ship units and other surface type units. Requirements are also given for non-watertight bulkheads.

7.1.2 The scantlings of bulkhead structures are to comply with:

- Part 10 for ship units; and
- Ch 4,4 for other surface type units.

7.1.3 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent end support and alignment are provided.

7.1.4 The number and disposition of watertight bulkheads are to be in accordance with Ch 3,5 and the requirements of Chapter 7 regarding watertight integrity are to be complied with.

7.1.5 The buckling requirements of Ch 5,4 are also to be satisfied.

7.1.6 The height of the air and overflow pipes are to be clearly indicated on the plans submitted for approval and the load heads for scantlings are to be not less than those defined in Table 6.7.1.

7.2 Symbols

7.2.1 The following symbols are applicable to this Section:

k = higher tensile steel factor, *see* Ch 2,1
s = spacing of secondary stiffeners, in mm
I = inertia of stiffening member, in cm^4, *see* Ch 3,3
S = spacing or mean spacing of primary members, in metres
Z = section modulus of stiffening member, in cm^3, *see* Pt 3, Ch 3,3
ρ = relative density (specific gravity) of liquid carried in a tank, but is not to be taken less than 1,025.

7.3 Watertight and deep tank bulkheads

7.3.1 The scantlings of watertight and deeptank bulkheads are to comply with the requirements of Tables 6.7.1 to 6.7.3. Where tanks cannot be inspected at normal periodic surveys, the scantlings derived from this Section are to be suitably increased.

7.3.2 Where bulkhead stiffeners support deck girders, transverses or pillars over, the scantlings are to satisfy the requirements of Section 4.

7.3.3 The strength of bulkheads and flats which support the ends of bracings or columns will be specially considered.

7.3.4 In way of partially filled tanks, the scantlings and structural arrangements of the boundary bulkheads are to be capable of withstanding the loads imposed by the movement of the liquid in those tanks. The magnitude of the predicted loadings, together with the scantling calculations, may require to be submitted, *see also* Ch 3,4.18.

Table 6.7.1 Watertight and deep tank bulkhead scantlings

Item and requirement	Watertight bulkheads	Deep tank bulkheads
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	$t = 0{,}004sf\sqrt{h_4 k}$ mm but not less than 5,5 mm	$t = 0{,}004s\,f\sqrt{\dfrac{\rho\, h_4\, k}{1{,}025}} + 2{,}5$ mm nor less than 7,5 mm
	In the case of symmetrical corrugations, *s* is to be taken as *b* or *c* in Fig. 3.3.1 in Chapter 3, whichever is the greater	
(2) Modulus of rolled and built stiffeners, swedges, double plate bulkheads and symmetrical corrugations	$Z = \dfrac{s\,k\,h_4\,l_e^2}{71\gamma\,(\omega_1 + \omega_2 + 2)}$ cm^3	$Z = \dfrac{\rho\,s\,k\,h_4\,l_e^2}{22\gamma\,(\omega_1 + \omega_2 + 2)}$ cm^3
	In the case of symmetrical corrugations, *s* is to be taken as *p*, *see also* Note 2	
(3) Inertia of rolled and built stiffeners and swedges	—	$I = \dfrac{2{,}3}{k}\,l_e Z$ cm^3
(4) Symmetrical corrugations and double plate bulkheads	Additional requirements to be complied with as detailed in Table 6.7.2	
(5) Stringers or webs supporting vertical or horizontal stiffening (a) Modulus (b) Inertia	$Z = 5{,}5k\,h_4 S\,l_e^2$ cm^3 —	$Z = 11{,}7\rho\,k\,h_4\,S\,l_e^2$ cm^3 $I = \dfrac{2{,}5}{k}\,l_e Z$ cm^3

Symbols

s, *S*, I, *k*, ρ as defined in 7.2.1

d_w = web depth of stiffening member, in mm

$f = 1{,}1 - \dfrac{s}{2500S}$ but not to be taken greater than 1,0

h_4 = load head, in metres measured vertically as follows:

(a) For watertight bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to a point 0,91 m above the bulkhead deck at side or to the worst damage waterline, whichever is the greater

(b) For tank bulkhead plating, the distance from a point one-third of the height of the plate above its lower edge to the top of the tank, or half the distance to the top of the overflow, whichever is the greater

(c) For watertight bulkhead stiffeners or girders, the distance from the middle of the effective length to a point 0,91 m above the bulkhead deck at side or to the worst damage waterline, whichever is the greater

(d) For tank bulkhead stiffeners or girders, the distance from the middle of the effective length to the top of the tank, or half the distance to the top of the overflow, whichever is the greater

l_e = effective length of stiffening member, in metres, and for bulkhead stiffeners, to be taken as $l - e_1 - e_2$, *see also* Fig. 6.7.1

p = spacing of corrugations as shown in Fig. 3.3.1 in Chapter 3

γ = 1,4 for rolled or built sections and double plate bulkheads
= 1,6 for flat bars
= 1,1 for symmetrical corrugations of deep tank bulkheads
= 1,0 for symmetrical corrugations of watertight bulkheads

ω, *e* = as defined in Table 6.7.3, *see also* Fig. 6.7.1

NOTES

1. In no case are the scantlings of deep tank bulkheads to be less than the requirements for watertight bulkheads where the boundary bulkheads of the tanks form part of the watertight sub-division of the unit to meet damage stability requirements, *see* Ch 3,5.
2. For self-elevating units, the bulkhead deck is to be taken as the freeboard deck.
3. For column-stabilised units, the bulkhead deck is, in general, to be taken as the uppermost continuous strength deck unless agreed otherwise with LR.
4. The scantlings of all void compartments adjacent to the sea are also to comply with 7.5.1.
5. In calculating the actual modulus of symmetrical corrugations the panel width *b* is not to be taken greater than that given by Ch 3,3.2.
6. For rolled or built stiffeners with flanges or face plates, the web thickness is to be not less than $\dfrac{d_w}{60\sqrt{k}}$ whilst for flat bar stiffeners the web thickness is to be not less than $\dfrac{d_w}{18\sqrt{k}}$.

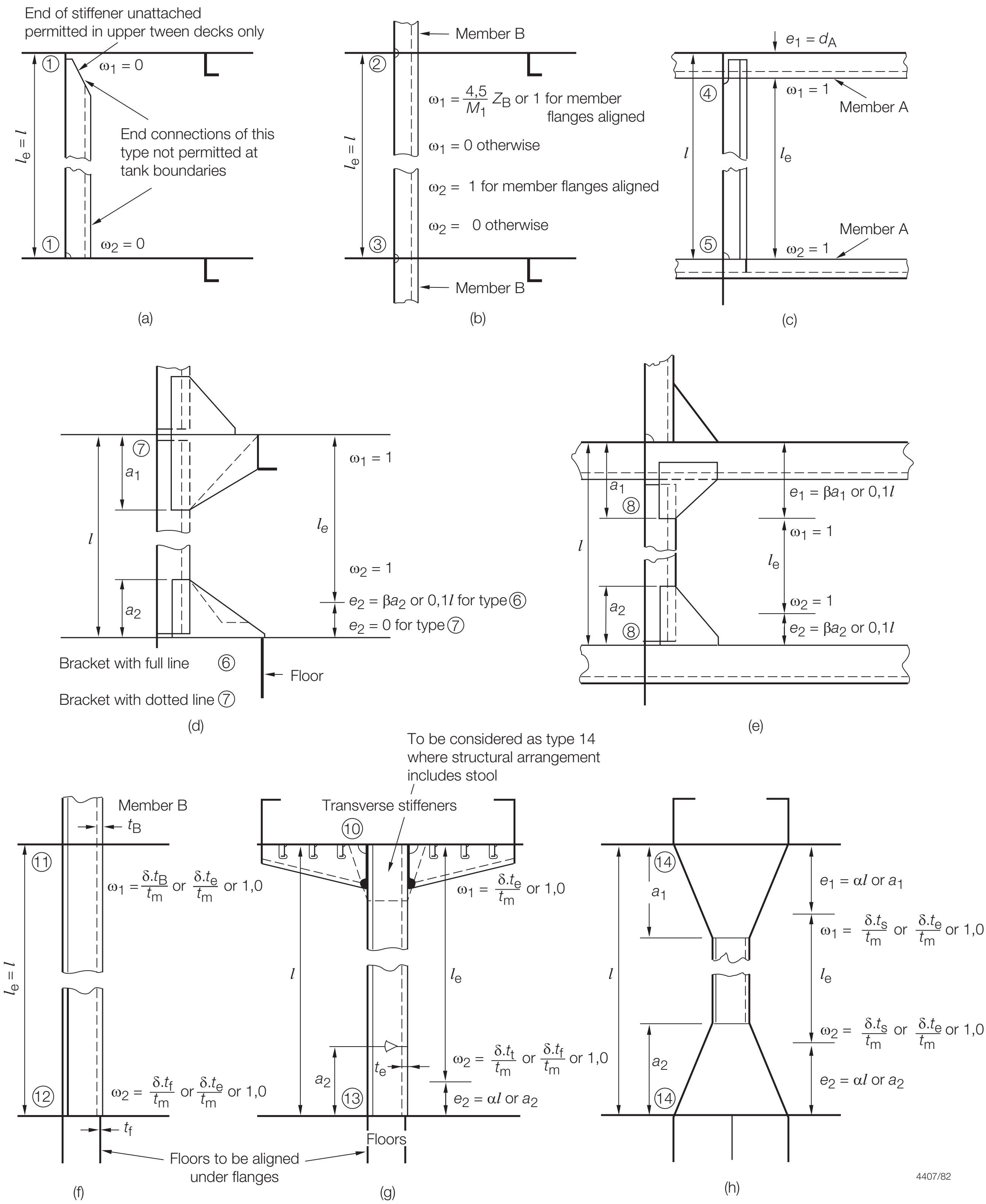


Fig. 6.7.1 Effective length and end constraint definitions for bulkheads

Table 6.7.2 Symmetrical corrugations and double plate bulkheads (additional requirements)

Symbols	Type of bulkhead	Parameter	Watertight bulkheads	Deep tank bulkheads
s, *k* as defined in 6.2.1 b = panel width as shown in Fig. 3.3.1 in Chapter 3 d = depth, in mm, of symmetrical corrugation or double plate bulkhead l_e as defined in Table 6.7.1 A_w = shear area, in cm^2, of webs of double plate bulkhead θ = angle of web corrugation to plane of bulkhead	Symmetrically corrugated, *see also* Notes 1 and 2	$\dfrac{b}{t}$	Not to exceed: $85\sqrt{k}$ at top, and $70\sqrt{k}$ at bottom	Not to exceed: $70\sqrt{k}$ at top and bottom
			See also Note 4	
		d	—	To be not less than: $39 l_e$ mm
		θ	To be not less than 40°	
NOTES 1. The plating thickness at the middle of span l_e of corrugated or double plate bulkheads is to extend not less than $0{,}2 l_e$ m above mid-span. 2. Where the span of corrugations exceeds 15 m, a diaphragm plate is to be arranged at about mid-span. 3. *See also* Chapter 8. 4. In calculating the actual modulus of symmetrical corrugations, the panel width *b* is not to be taken greater than that given by Ch 3,3.2.	Double plate, *see also* Note 3	$\dfrac{s}{t}$	Not to exceed: $75\sqrt{k}$ at top, and $65\sqrt{k}$ at bottom	
		$\dfrac{d}{t_w}$	Not to exceed: $85\sqrt{k}$ at top, and $75\sqrt{k}$ at bottom	
		d	—	To be not less than: $39 l_e$ mm
		A_w	To be not less than: $\dfrac{0{,}12Z}{l_e}$ cm^2 at top, and $\dfrac{0{,}18Z}{l_e}$ cm^2 at bottom	$\dfrac{0{,}07Z}{l_e}$ cm^2 at top, and $\dfrac{0{,}10Z}{l_e}$ cm^2 at bottom

7.3.5 In deep tanks, oil fuel or other liquids are to have a flash point of 60°C or above (closed-cup test). Where tanks are intended for liquids of a special nature, the scantlings and arrangements will be specially considered in relation to the properties of the liquid, *see* 7.3.6. For the scantlings of mud tanks, *see* 7.6.

7.3.6 Where tanks are intended for the storage of oil with a flash point less than 60°C (closed-cup test) the scantlings of bulkheads are to comply with:

- Part 10 for ship units.
- Ch 4,4 for other surface-type units.
- This Section for other unit types.

The minimum scantlings and arrangements on all units are also to comply with Pt 3, Ch 3.

7.3.7 For cofferdams on units with oil storage tanks, as defined in 7.3.6, the separation of tanks and spaces are to comply with Pt 3, Ch 3. Cofferdams are to be fitted between tanks as necessary, depending on the liquids stored. In general, cofferdams are to be fitted between tanks in accordance with the requirements of Ch 3,5.

7.3.8 Where watertight bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced. Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration. Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

7.3.9 Wash bulkheads or divisions are to be fitted to deep tanks as required by Ch 7,4. The division bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the plating thickness is not to be less than 7,5 mm and the modulus of the stiffeners may be 50 per cent of that required for boundary bulkheads, using h_4 measured to the crown of the tank. The stiffeners are to be bracketed at top and bottom. The area of perforation is to be not less than five per cent nor more than 10 per cent of the total area of the bulkhead. Where brackets from horizontal girders on the boundary bulkheads terminate at the centreline bulkhead, adequate support and continuity are to be maintained.

7.3.10 The scantlings of end brackets fitted to bulkhead stiffeners are, in general, to comply with Chapter 8.

Table 6.7.3 Bulkhead end constraint factors (*see continuation*)

Type	End connection, *see* Fig. 6.7.1			ω	e	μ
Rolled or built stiffeners and swedges						
1	End of stiffeners unattached or attached to plating only			0	0	—
2	Members with webs and flanges (or bulbs) in line and attached at deck or horizontal girder *See also* Note 1	Adjacent member of B of smaller modulus		The lesser of $\frac{4,5Z_B}{M_1}$ or 1,0	0	—
3		Adjacent member B of same or larger modulus		1,0	0	—
4	Bracketless connection to longitudinal member	Member A within length l		1,0	$\frac{d_A}{1000}$	—
5		Member A outside length l		1,0	0	—
6	Bracketed connection	To transverse member	Bracket extends to floor	1,0	The lesser of βa or $0,1l$	—
7			Otherwise	1,0	0	—
8		To longitudinal member		1,0	The lesser of βa or $0,1l$	—
Symmetrical corrugations or double plate bulkheads						
9	Welded directly to deck – no bulk-head in line	No longitudinal brackets		0	0	—
10		With longitudinal brackets and trans-verse stiffeners supporting corrugated bulkhead		The lesser of $\frac{\delta\, t_e}{t_m}$ or 1,0	0	—
11	Welded directly to deck or girder	Bulkhead B, having same section, in line		The least of $\frac{\delta t_B}{t_m}$ or $\frac{\delta t_e}{t_m}$ or 1,0	0	—
12	Welded directly to tank top and effectively supported by floors in line with each bulkhead flange, *see also* Note 2	Thickness at bottom same as that at mid-span		The least of $\frac{\delta t_f}{t_m}$ or $\frac{\delta t_e}{t_m}$ or 1,0	0	—
13		Thickness at bottom greater than that at mid-span		The least of $\frac{\delta t_f}{t_m}$ or $\frac{\delta t_e}{t_m}$ or 1,0	The lesser of αl or a	The lesser of $\frac{t_f}{t_m}$ or $\frac{t_e}{t_m}$
14	Welded to stool efficiently supported by the unit's structure			For deep tank bulkheads 1,0 For watertight bulkheads the least of $\frac{\delta t_f}{t_m}$ or $\frac{\delta t_e}{t_m}$ or 1,0	The lesser of αl or a	$\frac{10Z_s}{M_2}$

Table 6.7.3 Bulkhead end constraint factors (*conclusion*)

Symbols	
s, l, ρ, k, as defined in 7.2.1 a = height, in metres, of bracket or end stool or lowest strake of plating of symmetrically corrugated or double plate bulkheads, *see* Fig. 6.7.1 d_A = web overall depth, in mm, of adjacent member A e = effective length, in metres, of bracket or end stool, *see* Fig. 6.7.1 h_o = h_4 but measured from the middle of the overall length l l_e, p, h_4 as defined in Table 6.7.1 t_f = thickness of supporting floor, in mm t_m, t_e = thickness, in mm, of flange plating of corrugation or double plate bulkhead at mid-span or end, respectively t_s = thickness, in mm, of stool adjacent to bulkhead t_B = thickness, in mm, of flange plating of member B Subscripts 1 and 2, when applied to ω, e and a, refer to the top and bottom ends of stiffener respectively $M_1 = \dfrac{h_4\, s\, l_e^2}{71}$ for watertight bulkheads $= \dfrac{\rho\, h_4\, s\, l_e^2}{22}$ for deep tank bulkheads $M_2 = \dfrac{h_o\, s\, l^2}{71}$ for watertight bulkheads $= \dfrac{\rho h_o\, s\, l^2}{22}$ for deep tank bulkheads In the case of symmetrical corrugations $s = p$ Z_s = section modulus, in cm^3, of horizontal section of stool adjacent to deck or tank top over breadth s or p (as applicable) All material which is continuous from top to bottom of stool may be included in the calculation	Z_B = section modulus, in cm^3, of adjacent member B α = a factor depending on μ and determined as follows: where $\mu \leq 1{,}0$ $\alpha = 0$ where $\mu > 1{,}0$ $\alpha = 0{,}5 - \dfrac{1}{\sqrt{2\mu + 2}}$ β = a factor depending on the end bracket stiffening and to be taken as: 1,0 for brackets with face bars directly connected to stiffener face bars 0,7 for flanged brackets 0,5 for unflanged brackets δ = 1,0 generally $\delta = \dfrac{0{,}932\sqrt{k}}{\xi}$ for corrugated watertight bulkheads η = lesser of 1,0 and $\dfrac{50 t_m \sqrt{k}}{b}$ for welded sections η = lesser of 1,0 and $\dfrac{60 t_m \sqrt{k}}{b}$ for cold formed sections μ = a factor representing end constraint for symmetrical corrugation and double plate bulkheads ξ = 1,0 where full continuity of corrugation webs is provided at the ends ξ = greater of 1,0 and (η + 0,333) where full continuity is not provided ω = an end constraint factor relating to the different types of end connection, *see* Fig. 6.7.1

NOTES
1. Where the end connection is similar to type 2 or 3, but member flanges (or bulbs) are not aligned and brackets are not fitted, $\omega = 0$.
2. Where the end connection is similar to type 12 or 13, but a transverse girder is arranged in place of one of the supporting floors, special consideration will be required.

7.4 Watertight flats, trunks and tunnels

7.4.1 The scantlings and arrangements of watertight flats, trunks and tunnels are to be equivalent to the requirements for watertight bulkheads or tanks as defined in 7.3 as appropriate. The scantlings of shaft tunnels will be specially considered. The scantlings at the crown or bottom of tanks are to comply with the requirements of Table 6.4.1.

7.4.2 Additional strengthening is to be fitted to tunnels under the heels of pillars, as necessary.

7.5 Watertight void compartments

7.5.1 In all units where watertight void compartments are adjacent to the sea, the scantlings of the boundary bulkheads are to be determined from Table 6.7.1 for watertight bulkheads but the scantlings are not to be less than required for tank bulkheads using the load head h_4, measured to the maximum operating draught of the unit.

7.6 Mud tanks

7.6.1 The scantlings of mud tanks are to be not less than those required for tanks using the design density of mud. However, in no case is the relative density of wet mud to be taken as less than 2,2 unless agreed otherwise with LR.

7.7 Non-watertight bulkheads

7.7.1 The scantlings of non-watertight bulkheads supporting decks are to be in accordance with Table 6.4.5.

■ *Section 8*
Double bottom structure

8.1 Symbols and definitions

8.1.1 The symbols used in this Section are defined as follows:

L, T_0 and T_T as defined in Ch 1,5

B as defined in Ch 1,5 but need not exceed B_1

B_1 = maximum distance between longitudinal bulkheads, in metres

d_{DB} = Rule depth of centre girder, in mm

d_{DBA} = actual depth of centre girder, in mm

h_{DB} = head from top of inner bottom to top of overflow pipe, in metres

h_4 = load head as defined in Table 6.7.1

s = spacing of stiffeners, in mm.

8.2 General

8.2.1 In general, double bottoms need not be fitted in non-propelled units and column-stabilised units, except where required by a National Administration.

8.2.2 Where double bottoms are fitted, the scantlings are to comply with:

- Part 10 for ship units.
- Ch 4,4 for other surface-type units.
- This Section for other unit types.

8.2.3 The requirements in this Section are, in general, applicable to double bottoms with stiffeners fitted parallel to the hull bending compressive stress. When other stiffening arrangements are proposed the scantlings will be specially considered, but the minimum requirements of this Section are to be complied with.

8.2.4 The arrangements of drainage wells, recesses and dump valves in the double bottom will be specially considered.

8.2.5 If it is intended to dry-dock the unit, girders and the side walls of duct keels are to be continuous and the structure is to have adequate strength to withstand the forces imposed by dry-docking the unit.

8.2.6 Adequate access is to be provided to all parts of the double bottom. The edges of all holes are to be smooth. The size of the opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

8.2.7 Provision is to be made for the free passage of air and water from all parts of tank spaces to the air pipes and suctions, account being taken of the pumping rates required. To ensure this, sufficient air holes and drain holes are to be provided in all longitudinal and transverse non-watertight primary and secondary members. The drain holes are to be located as close to the bottom as is practicable, and air holes are to be located as close to the inner bottom as is practicable, *see also* Pt 3, Ch 8.

8.3 Self-elevating units

8.3.1 When a double bottom is fitted to a self-elevating unit, the scantlings of the double bottom will be specially considered in accordance with Ch 4,3 but the general requirements of this Section are to be complied with.

8.3.2 The longitudinal extent of the double bottom will be specially considered in respect of the design and safety of the unit but it should extend as far forward and aft as is practicable. A double bottom need not be fitted in pre-load deep tanks or other wing deep tanks.

8.3.3 The depth of the double bottom at the centreline, d_{DB}, is to be in accordance with 8.3.4 and the inner bottom is, in general, to be continued out to the unit's side in such a manner as to protect the bottom to the turn of bilge. When pre-load wing deep tanks are fitted port and starboard, the inner bottom may be terminated at the deep tank longitudinal bulkheads.

8.3.4 **The centre girder** is to have a depth of not less than that given by:

$$d_{DB} = 28B + 205\sqrt{T_T} \text{ mm}$$

nor less than 760 mm. The centre girder thickness is to be not less than:

$$t = (0{,}008d_{DB} + 4)\sqrt{k} \text{ mm}$$

nor less than 6,0 mm. The thickness may be determined using the value for d_{DB} without applying the minimum depth of 760 mm.

8.3.5 **Side girders** are to be fitted below longitudinal bulkheads. In general, one side girder is to be fitted where the breadth, B, exceeds 14 m and two side girders are to be fitted on each side of the centreline where B exceeds 21 m. Equivalent arrangements are to be provided where longitudinal bulkheads are fitted. The side girders are to extend as far forward and aft as practicable and are to have a thickness not less than:

$$t = (0{,}0075d_{DB} + 1)\sqrt{k} \text{ mm}$$

nor less than 6,0mm. In general, a vertical stiffener, having a depth not less than 100 mm and a thickness equal to the girder thickness, is to be arranged midway between floors.

8.3.6 **Watertight side girders** are to have a plating thickness corresponding to the greater of the following:

(a) $t = (0{,}0075d_{DB} + 2)\sqrt{k}$ mm, or

(b) Thickness, t, as for deep tanks, *see* 7.3, using the load head h_4 which, in the case of double bottom tanks which are interconnected to side tanks or cofferdams, is not to be less than the head measured to the highest point of the side tank or cofferdam.

8.3.7 If the depth of the watertight side girders exceeds 915 mm but does not exceed 2000 mm, the girders are to be fitted with vertical stiffeners spaced not more than 915 mm apart and having a section modulus not less than:

$$Z = 5{,}41 d_{DBA}^2\, h_{DB}\, s\, k \times 10^{-9} \quad \text{cm}^3$$

The ends of the stiffeners are to be sniped. Where the double bottom tanks are interconnected with side tanks or cofferdams, or where the depth of the girder exceeds 2000 mm, the scantlings of watertight girders are to be not less than those required for deep tanks, *see* 7.3, and the ends of the stiffeners are to be bracketed top and bottom.

8.3.8 **Duct keels**, where arranged, are to have a thickness of side plates corresponding to the greater of the following:

(a) $t = (0{,}008 d_{DB} + 2)\sqrt{k}$ mm, or

(b) Thickness, t, as for deep tanks, *see* 7.3, using the load head h_4 which, in the case of double bottom tanks which are interconnected to side tanks or cofferdams, is not to be less than the head measured to the highest point of the side tank or cofferdam.

8.3.9 The sides of the duct keels are, in general, to be spaced not more than 2,0 m apart. Where the sides of the ducts keels are arranged on either side of the centreline or side girder, each side is, in general, to be spaced not more than 2,0 m from the centreline or side girder. The inner bottom and bottom shell within the duct keel are to be suitably stiffened. The primary stiffening in the transverse direction is to be suitably aligned with the floors in the adjacent double bottom tanks. Where the duct keels are adjacent to double bottom tanks which are interconnected with side tanks or cofferdams, the stiffening is to be in accordance with the requirements for deep tanks, *see* 7.3. Access to the duct keel is to be by watertight manholes or trunks.

8.3.10 **Inner bottom plating** is, in general, to have a thickness not less than:

$$t = 0{,}00136\,(s + 660)\,(k^2\, L\, T_T)^{1/4} \text{mm}$$

nor less than 6,5 mm.

8.3.11 The thickness of the inner bottom plating as determined in 8.3.10 is to be increased by 10 per cent in machinery spaces but in no case is the thickness to be less than 7,0 mm.

8.3.12 A margin plate, if fitted, is to have a thickness throughout 20 per cent greater than that required for inner bottom plating.

8.3.13 Where the double bottom tanks are common with side tanks or cofferdams, the thickness of the inner bottom plating is to be not less than that required for deep tanks, *see* 7.3, and the load head h_4 is to be measured to the highest point of the side tank or cofferdam.

8.3.14 **Inner bottom stiffeners** are in general to have a section modulus not less than 85 per cent of the Rule value for bottom shell stiffeners, *see* 3.3.1. When the inner bottom design loading is considerably less than $9{,}82 T_T$ kN/m^2 (T_T tonne-f/m^2) the scantlings of the inner bottom stiffeners will be specially considered. Where the double bottom tanks are interconnected with side tanks or cofferdams, the scantlings are to be not less than those required for deep tanks, *see* 7.3.

8.3.15 **Plate floors** are to be fitted under heavy machinery items and under bulkheads and elsewhere at a spacing not exceeding 3,8 m. The thickness of non-watertight plate floors is to be not less than:

$$t = (0{,}009 d_{DB} + 1)\sqrt{k} \quad \text{mm}$$

nor less than 6,0 mm. The thickness need not be greater than 15 mm, but the ratio between the depth of the double bottom and the thickness of the floor is not to exceed $130\sqrt{k}$. This ratio may, however, be exceeded if suitable additional stiffening is fitted. Vertical stiffeners are to be fitted at each bottom shell stiffener, having a depth not less than 150 mm and a thickness equal to the thickness of the floors. For units of length, L, less than 90 m, the depth is to be not less than 1,65L mm, with a minimum of 50 mm.

8.3.16 **Watertight floors** are to have thickness not less than:

(a) $t = (0{,}008 d_{DB} + 3)\sqrt{k}$ mm, or

(b) $t = (0{,}009 d_{DB} + 1)\sqrt{k}$ mm,

whichever is the greater, but not to exceed 15 mm on floors of normal depth. The thickness is also to satisfy the requirements for deep tanks, *see* 7.3, with the load head h_4 measured to the highest point of the side tank or cofferdam if the double bottom tank is interconnected with these tanks. The scantlings of the stiffeners are to be in accordance with the requirements of 7.3 for deep tanks, but in no case is the modulus to be less than:

$$Z = 5{,}41 d_{DBA}^2\, h_{DB}\, s\, k \times 10^{-9} \quad \text{cm}^3$$

Vertical stiffeners are to be connected to the inner bottom and shell stiffeners.

8.3.17 Between plate floors, transverse brackets having a thickness not less than $0{,}009 d_{DB}$ mm are to be fitted, extending from the centre girder and margin plate to the adjacent longitudinal. The brackets, which are to be suitably stiffened at the edge, are to be fitted at every frame at the margin plate, and those at the centre girder are to be spaced not more than 1,25 m.

8.3.18 Where floors form the boundary of a sea inlet box, the thickness of the plating is to be the same as the adjacent shell, but not less than 12,5 mm. The scantlings of stiffeners, where required are, in general, to comply with 7.3 for deep tanks. Sniped ends for stiffeners on the boundaries of these spaces are to be avoided wherever practicable. The stiffeners should be bracketed or the free end suitably supported to provide alignment with backing structure.

8.4 Column-stabilised, tension-leg, deep draught caisson, buoy, and sea bed-stabilised units

8.4.1 Where a double bottom is fitted in the lower hull of column-stabilised, tension-leg, deep draught caisson, buoy or sea bed-stabilised units, the scantlings of the double bottom structure will be specially considered but the general requirements of 8.3 are to be complied with where applicable. The minimum scantlings of the double bottom structure are to be in accordance with 8.4.2.

8.4.2 The scantlings of tank boundaries are to comply with the requirements for tank bulkheads in Section 7 but the load head h_4 is not to be taken less than the distance measured to T_0. When the internal double bottom compartment is a void space the scantlings of watertight boundaries are to comply with 7.5.1 and Table 6.7.1.

8.4.3 The boundaries of a sea inlet box are to comply with the requirements of 8.3.18.

8.4.4 The strength of the bottom structures in sea bed-stabilised units is also to comply with Ch 4,2.1.6.

■ *Section 9* Superstructures and deckhouses

9.1 General

9.1.1 The term 'erection' is used in this Section to include both superstructures and deckhouses.

9.1.2 Erections are to comply with

- Part 10 for ship units.
- Ch 4,4 for other surface-type units.
- This Section for other unit types.

Units with a Rule length, *L*, greater than 150 m will be specially considered.

9.1.3 The scantlings of exposed bulkheads and decks of deckhouses are generally to comply with the requirements of this Section, but increased scantlings may be required where the structure is subjected to local loadings greater than those defined in the Rules, *see also* 9.1.6. Where there is no access from inside the house to below the freeboard deck or into buoyant spaces included in stability calculations, or where a bulkhead is in a particularly sheltered location, the scantlings may be specially considered.

9.1.4 The scantlings of superstructures which form an extension of the side shell or which form an integral part of the unit's hull and contribute to the overall strength of the unit will be specially considered. The upper hull structure of column-stabilised units are to comply with Section 3.

9.1.5 Any exposed part of an erection which may be subject to immersion in damage stability conditions and which could result in down flooding is to have scantlings not less than required for watertight bulkheads given in Section 7.

9.1.6 The boundary bulkheads of accommodation spaces which may be subjected to blast loading are to comply with Ch 3,4 and permissible stress levels are to satisfy the factors of safety given in Ch 5,2.1.1(c).

9.1.7 The scantlings of erections used for helicopter landing areas are also to comply with Section 5.

9.1.8 For requirements relating to companionways, doors and hatches, *see* Chapter 7.

9.2 Symbols

9.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B, T_T and C_b as defined in Ch 1,5.1.

b = breadth of deckhouse, at the positions under consideration, in metres

k = higher tensile steel factor, *see* Ch 2,1.2

l_e = effective length, in metres, of the stiffening member, deck beam or longitudinal measured between span points, *see* Ch 3,3.3

l_s = span, in metres, of erection stiffeners and is to be taken as the 'tween deck or house height but in no case less than 2,0 m

s = spacing of stiffeners, beams or longitudinals, in mm

s_b = standard spacing, in mm, of stiffeners, beams or longitudinals, and is to be taken as:

(a) for 0,05L from the ends:
s_b = 610 mm or that required by (b), whichever is the lesser

(b) elsewhere:
s_b = 470 + 1,67L_2 mm
but forward of 0,2L from the forward perpendicular s_b is not to exceed 700 mm

B_1 = actual breadth of unit at the section under consideration, measured at the weather deck, in metres

L_2 = length of unit in metres, but need not be taken greater than 250 m

L_3 = length of unit in metres, but need not be taken greater than 300 m

D = moulded depth of unit, in metres, to the uppermost continuous deck

X = distance, in metres, between the after perpendicular and the bulkhead under consideration. When determining the scantlings of deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length not exceeding 0,15L each, and X is to be measured to the mid-length of each part

α = a coefficient given in Table 6.9.1

$$\beta = 1{,}0 + \left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{(C_b + 0{,}2)}\right)^2 \quad \text{for } \frac{X}{L} \leq 0{,}45$$

$$= 1{,}0 + 1{,}5\left(\frac{\left(\frac{X}{L} - 0{,}45\right)}{(C_b + 0{,}2)}\right)^2 \quad \text{for } \frac{X}{L} > 0{,}45$$

C_b is to be taken not less than 0,6 nor greater than 0,8. Where the aft end of an erection is forward of amidships, the value of C_b used for determining β for the aft end bulkhead is to be taken as 0,8

γ = vertical distance, in metres, from the maximum transit waterline to the mid-point of span of the bulkhead stiffener, or the mid-point of the plate panel, as appropriate

δ = 1,0 for exposed machinery casings and $\left(0,3 + 0,7\,\dfrac{b}{B_1}\right)$ elsewhere, but in no case to be taken less than 0,475

λ = a coefficient given in Table 6.9.2.

Table 6.9.1 Values of α

Position		α
Lowest tier	– unprotected front	$2,0 + 0,0083L_3$
Second tier	– unprotected front	$1,0 + 0,0083L_3$
Third tier and above All tiers All tiers	– unprotected front – protected fronts – sides	$0,5 + 0,0067L_3$
All tiers	– aft end where aft of amidships	$0,7 + 0,001L_3 - 0,8\,\dfrac{X}{L}$
All tiers	– aft end where forward of amidships	$0,5 + 0,001L_3 - 0,4\,\dfrac{X}{L}$

9.3 Definition of tiers

9.3.1 The first, or the lowest tier, is an erection situated on the deck to which *D* is measured. The second tier is the next tier above the lowest tier, and so on.

9.3.2 For self-elevating units where the freeboard corresponding to the required summer moulded draught for the unit can be obtained by considering the unit to have a virtual moulded depth of at least one standard superstructure height less than the Rule depth, *D*, measured to the uppermost continuous deck, proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in the *International Convention on Load Lines, 1966*.

9.4 Design pressure head

9.4.1 The design pressure head, *h*, to be used in the determination of erection scantlings is to be taken as:

$$h = \alpha\,\delta\,(\beta\,\lambda - \gamma) \quad \text{m}$$

9.4.2 In no case is the design pressure head to be taken as less than the following:

(a) Lowest tier of unprotected fronts:
minimum $h = 2,5 + 0,01L_2$ m

Table 6.9.2 Values of λ

Length L in metres	λ	Expression for λ
20 30 40 50 60 70 80 90 110 130 150	0,89 1,76 2,57 3,34 4,07 4,76 5,41 6,03 7,16 8,18 9,10	$L \leq 150$ m $\lambda = \left(\dfrac{L}{10}e^{-\frac{L}{300}}\right) - \left(1 - \left(\dfrac{L}{150}\right)^2\right)$
150 170 190 210 230 250 270 290 300	9,10 9,65 10,08 10,43 10,69 10,86 10,98 11,03 11,03	150 m $\leq L \leq$ 300 m $\lambda = \dfrac{L}{10}e^{-\frac{L}{300}}$
300 and above	11,03	$L \geq 300$ m $\lambda = 11,03$

(b) All other locations:
minimum $h = 1,25 + 0,005L_2$ m

9.5 Bulkhead plating and stiffeners

9.5.1 The plating thickness, *t*, of fronts, sides and aft ends of all erections other than the sides of the superstructures where these are an extension of the side shell, is not to be less than:

$$t = 0,003s\sqrt{k\,h} \quad \text{mm,}$$

but in no case is the thickness to be less than:

(a) for the lowest tier:
$t = (5,0 + 0,01L_3)\sqrt{k}$ mm,
but not less than 5,0 mm.

(b) for the upper tiers:
$t = (4,0 + 0,01L_3)\sqrt{k}$ mm,
but not less than 5,0mm.

9.5.2 The thickness of sides of forecastles, bridges and poops is to be as required by Ch 4,4.

9.5.3 The modulus of stiffeners, *Z*, on fronts, sides and end bulkheads of all erections, other than the sides of superstructures where these are an extension of the side shell, is to be not less than:

$$Z = 0,0035h\,s\,l_s^2\,k \quad \text{cm}^3$$

9.5.4 The end connections of stiffeners are to be as given in Table 6.9.3.

9.5.5 The section modulus of side frames of forecastles, bridges and poops is to be as required by Ch 4,4.

Table 6.9.3 Stiffener end connections

Position	Attachment at top and bottom
1. Front stiffeners of lower tiers and of upper tiers when L is 160 m or greater	*See* Chapter 8 *See* Note
2. Front stiffeners of upper tiers when L is less than 160 m	May be unattached
3. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round
4. Side stiffeners if only one tier is fitted, and aft end stiffeners of after deck-houses on deck to which D is measured	*See* Chapter 8
5. Side stiffeners of upper tiers where L is 160 m or greater	*See* Chapter 8
6. Side stiffeners of upper tiers when L is less than 160 m	May be unattached
7. Aft end stiffeners except as covered by item 4	May be unattached
8. Exposed machinery and pump-room casings. Front sitffeners on amid-ship casings and all stiffeners on aft end casings which are situated on the deck to which D is measured	Bracketed
9. All other stiffeners on exposed machinery and pump-room casings	6,5 cm^2 of weld
NOTE Front stiffeners of lower tiers on self-elevating units are to be bracketed.	

9.6 Erections on self-elevating units

9.6.1 The scantlings of exposed ends and sides of erections are to comply with 9,5, but the additional requirements of this sub-Section are to be complied with.

9.6.2 The plating thickness, t, of exposed lower tier fronts is to be not less than:

$$t = 0{,}0036s\sqrt{k\,h} \quad \text{mm}$$

but in no case is the thickness to be less than 7,0 mm.

9.6.3 The modulus of stiffeners, Z, on exposed lowest tier fronts is to be not less than:

$$Z = 0{,}0044h\,s\,l_s^2\,k \quad \text{cm}^3$$

9.6.4 Where the exposed side of an erection is close to the side shell of the unit, the scantlings may be required to conform to the requirements for exposed bulkheads of unprotected house fronts.

9.6.5 The scantlings of jackhouses will be specially considered, but are not to be less than the scantlings that would be required for an erection at the same location.

9.6.6 The end connections of stiffeners are to be as given in Table 6.9.3.

9.7 Erections on other unit types

9.7.1 Where the erection can be subjected to wave forces, the scantlings of exposed ends and sides of erections are to comply with 9.5.

9.7.2 When the erection is not subjected to wave forces in any condition then the structure is to be suitable for the maximum design loadings but the minimum scantlings of exposed sides and ends of all erections is to be not less than:

(a) for the lowest tier:

$$t = (5{,}0 + 0{,}01L)\sqrt{k} \quad \text{mm, but not less than 5,0 mm.}$$

(b) for the upper tiers:

$$t = (5{,}0 + 0{,}01L)\sqrt{k} \quad \text{mm, but not less than 5,0 mm.}$$

9.7.3 The modulus of stiffeners, Z, of exposed sides and ends of all erections is to be not less than:

$$Z = 0{,}0035h\,s\,l_s^2\,k \quad \text{cm}^3$$

where

h = 1,25 + 0,005L m.

9.7.4 The end connections of stiffeners not subjected to wave loadings are to be as given in Table 6.9.4.

Table 6.9.4 Other unit types stiffener end connections

Position	Attachment at top and bottom
1. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all around
2. Side stiffeners if only one tier is fitted	*See* Chapter 8
3. All other stiffeners	May be unattached

9.8 Deck plating

9.8.1 In general, the thickness of erection deck plating is to be not less than that required by Table 6.9.5.

9.8.2 For erections not subjected to wave forces in any condition, the thickness of erection deck plating for all tiers need not exceed the requirements given in Table 6.9.5 for third tier erections, using:

s_b = 470 + 1,67L_2.

Table 6.9.5 **Thickness of deck plating**

Position	Thickness of deck plating, in mm		
	$L \leq 100$ m		$L > 100$ m
Top of first tier erection	$(5{,}5 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$	but not less than 5,0 mm	$7{,}5\sqrt{\dfrac{ks}{s_b}}$
Top of second tier erection	$(5{,}0 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$		$7{,}0\sqrt{\dfrac{ks}{s_b}}$
Top of third tier and above	$(4{,}5 + 0{,}02L)\sqrt{\dfrac{ks}{s_b}}$		$6{,}5\sqrt{\dfrac{ks}{s_b}}$
NOTE For units not subjected to wave loading, *see* 9.8.2.			

9.8.3 When decks are fitted with approved sheathing, the thickness derived from Table 6.9.5 may be reduced by 10 per cent for a 50 mm sheathing thickness, or five per cent for 25 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck. Inside erections the thickness may be reduced by a further 10 per cent. In no case is the deck thickness to be less than 5,0 mm.

9.8.4 The thickness, t, of forecastle deck plating is to be not less than:

$$t = (6 + 0{,}017L)\sqrt{\frac{ks}{s_b}} \quad \text{mm.}$$

9.9 Deck stiffening

9.9.1 The requirements for deck stiffeners in this sub-Section are applicable to both beams and longitudinals.

9.9.2 Deck stiffeners on deckhouses are to have a section modulus, Z, not less than:

$$Z = 0{,}0048 h_6\, s\, l_e^2\, k \ \text{cm}^3\text{, but in no case less than:}$$

$$Z = 0{,}025 s \quad \text{cm}^3$$

where the load head, h_6, is to be taken as not less than:

on first tier decks 0,9 m
on second tier 0,6 m
on third tier decks and above 0,45 m

but where the deck can be subjected to weather loading, the load, h_6, is to be increased in accordance with the requirements given in Table 6.2.1.

9.9.3 When deckhouses are subjected to specified deck loadings greater than the heads defined in 9.9.2 or are subjected to concentrated loads, equivalent load heads are to be used, *see* Table 6.2.1.

9.9.4 The section modulus of deck stiffeners on forecastles, bridges and poops is to be as required by Ch 4,4.

9.10 Deck girders and transverses

9.10.1 The scantlings of deck girders and transverses on erection decks are to be in accordance with the requirements of Table 6.4.3, using the appropriate load head, H_g, determined from Table 6.2.1.

9.11 Strengthening at ends and sides of erections

9.11.1 Web frames or equivalent strengthening are to be arranged to support the sides and ends of large erections.

9.11.2 These web frames should be spaced about 9 m apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boats davits and other points of high loading.

9.11.3 Arrangements are to be made to minimise the effect of discontinuities in erections. All openings cut in the sides are to be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings. Erections are to be strengthened in way of davits.

9.11.4 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.11.5 At the corners of deckhouses and in way of supporting structures, attention is to be given to the connection to the deck, and doublers or equivalent arrangements should generally be fitted.

9.12 Unusual designs

9.12.1 Where superstructures or deckhouses are of unusual design, the strength is to be not less than that required by this Section for a conventional design.

9.13 Aluminium erections

9.13.1 Where an aluminium alloy complying with Chapter 8 of the Rules for Materials is used in the construction of erections, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table 6.9.6.

9.13.2 The thickness, t, of aluminium alloy members is to be not less than:

$$t = 2{,}5 + 0{,}022 d_w \ \text{mm but need not exceed 10 mm}$$

where

d_w = depth of the section, in mm.

9.13.3 The minimum moment of inertia, I, of aluminium alloy stiffening members is to be not less than:

$$I = 5{,}25 Z\, l \quad \text{cm}^4$$

where l is the effective length of the member l_e or l_s, in metres, as defined in 9.2 and Z is the section modulus of the stiffener and attached plating in accordance with 9.4 and 9.9, taking k as 1.

Table 6.9.6 Percentage increase of scantlings

Item	Percentage increase
Fronts, sides, aft ends, unsheathed deck plating	20
Decks sheathed in accordance with 9.8.3	10
Deck sheathed with wood, and on which the plating is fixed to the wood sheathing at the centre of each beam space	Nil
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

9.13.4 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connections are to be submitted.

9.13.5 For aluminium alloy helicopter decks, *see* Section 6.

9.14 Fire protection

9.14.1 Fire protection of aluminium alloy erections is to be in accordance with the fire safety Regulations of the appropriate National Administration, *see* Pt 7, Ch 3.

9.14.2 Where it is proposed to use aluminium alloy for items or equipment in hazardous areas, incendive sparking may constitute a risk and full details are to be submitted for consideration.

■ *Section 10* Bulwarks and other means for the protection of crew and other personnel

10.1 General requirements

10.1.1 Bulwarks or guard rails are to be provided at the boundaries of weather decks and exposed freeboard and superstructure decks and deckhouses.

10.1.2 Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by 10.2 and 10.3. Consideration will be given to cases where this height would interfere with the normal operation of the unit.

10.1.3 The freeing arrangements in bulwarks are to be in accordance with 10.5.

10.1.4 Guard rails, as required by 10.1.1, are to consist of at least three courses and the opening below the lowest course is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. Where practicable, a toe plate 150 mm high is to be fitted below the lowest course. In the case of units with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

10.1.5 Satisfactory means, in the form of guard rails, lifelines, handrails, gangways, under-deck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the unit. For units with production and process plant, *see also* Pt 7, Ch 3.

10.1.6 Where access openings are required in bulwarks or guard rails, they are to be fitted with suitable gates and, in general, chains are not permitted where a person could fall into the sea.

10.1.7 Where gangways on a trunk are provided by means of a stringer plate fitted outboard of the trunk side bulkheads (port and starboard), each gangway is to be a solid plate, effectively stayed and supported, with a clear walkway at least 450 mm wide, at or near the top of the coaming, with guard rails complying with 10.1.4.

10.1.8 Where a National Administration has additional requirements for the protection of the crew or personnel on board, it is the Owners' responsibility to comply with all necessary Regulations.

10.2 Construction of bulwarks

10.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07L from the forward perpendicular is to be not more than 1,2 m on ship units and other surface type units and not more than 1,83 m on other unit types. Elsewhere, bulwark stays are to be not more than 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened where required to support additional loads or attachments and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

10.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses.

10.2.3 The section modulus, Z, at the bottom of the bulwark stay is to be not less than:

$$Z = (33{,}0 + 0{,}44L)\, h^2 s \ \text{cm}^3$$

where

h = height of bulwark from the top of the deck plating to the top of the rail, in metres

s = spacing of the stays, in metres, *see* 10.2.1

L = length of unit, in metres, but to be not greater than 100 m.

10.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the unit, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

10.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

10.2.6 When the bulwarks are required to support attachments or equipment for local operational or functional loads they are to be suitably strengthened.

10.3 Guard rail construction

10.3.1 Guard rails are, in general, to be constructed in accordance with a recognised Standard and the arrangement and spacing of guard rails are to comply with 10.1.4.

10.3.2 Stanchions are to be spaced not more than 1,5 m apart and the guard rails and their supports are to be designed to withstand a horizontal loading of 0,74 kN/m applied at the top rail. The permissible stresses in association with this loading are to be in accordance with Ch 5,2.1.1(a).

10.3.3 The stanchions and stays are to be supported by suitable under-deck stiffening.

10.3.4 When guard rails are required to support attachments for local operational or functional loads they are to be suitably strengthened.

10.4 Helicopter landing area

10.4.1 Safety nets are to be installed around the deck landing area, extending at least 1500 mm out from the perimeter. The netting is to be of approved material and of a flexible nature.

10.4.2 The safety net is to be supported at its outer edge and intermediate supports are to be spaced about 1,9 m apart. The supports are to be designed to withstand a concentrated load of 1,3 kN applied at any point on the supports. The permissible stresses are to satisfy the factors of safety given in Ch 5,2.1.1(a).

10.5 Freeing arrangements

10.5.1 In general, surface type oil storage units are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

10.5.2 For self-elevating units and on ship units and other surface type units, except where the additional requirements of 10.5.1 apply, the requirements of 10.5.3 to 10.5.18 are applicable.

10.5.3 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

10.5.4 The minimum freeing area on each side of the unit, for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the International Convention on Load Lines, 1966, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less: area required = $0,7 + 0,035l$ m^2

(b) where the length, l, exceeds 20 m: area required = $0,07l$ m^2

NOTE

l need not be taken greater than $0,7L_L$, where L_L is the load line length of the unit in accordance with the International Convention on Load Lines, 1966.

10.5.5 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

10.5.6 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 10.5.4.

10.5.7 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

10.5.8 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

10.5.9 In units with no sheer, the freeing area as calculated from 10.5.4 is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by linear interpolation.

10.5.10 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered, but in general need not exceed 10 per cent of the bulwark area.

10.5.11 Where it is not practical to provide sufficient freeing port area in the bulwark, credit can be given for bollard and fairlead openings where these extend to the deck.

10.5.12 Where a unit fitted with bulwarks has a continuous trunk or coamings, the requirements of 10.5.1 are to be complied with.

10.5.13 Where a deckhouse has a breadth less than 80 per cent of the beam of the unit, or the width of the side passageways exceeds 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam of the unit, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the unit, this arrangement is considered as two wells, before and abaft the deckhouse.

10.5.14 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

10.5.15 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck plant, etc., in which water may be shipped and trapped. Deck equipment is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

10.5.16 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

10.5.17 Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

10.5.18 Where shutters are fitted, the pins or bearings are to be of a non-corrodible material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port.

10.6 Deck drainage

10.6.1 Adequate drainage arrangements by means of scuppers are to be fitted as required by Ch 7,10.

■ *Section 11* Topside to hull structural sliding bearings

11.1 General

11.1.1 This Section covers the minimum technical requirements for the design, engineering, fabrication, assembly, inspection and testing of resilient bearing pads used as support interface between topside modules and the floating offshore installation.

11.1.2 Module bearing support arrangements are to be designed to ensure the effects of vessel deformations due to global hogging, sagging and torsion on the topside structure are minimised while moment transfer from the topside modules to the hull structure is kept to a minimum. In general this needs only to be considered for topsides modules where the support spacing is greater than three or more transverse frames.

11.2 Definitions, symbols and nomenclatures

11.2.1 For definitions, symbols and nomenclatures, *see* EN 1337 parts 1, 2, 3, 5 and 8 to 11.

11.3 References

EN 1337-1:2000, *Structural bearings – Part 1: General design rules*.
EN 1337-2:2004, *Structural bearings – Part 2: Sliding elements*.
EN 1337-2:2004, *Structural bearings – Part 3: Elastomeric bearings*.
EN 1337-8, *Structural bearings – Part 8: Guide bearings and restrain bearings*.
EN 1337: *Structural bearings – Part 5: European Standard, Construction standardisation: Pot bearing.*
EN 1337-9:1997, *Structural bearings – Part 9: Protection*.
EN 1337-10; *Structural bearings – Part 10: Inspection and maintenance*.
EN 1337-11; *Structural bearings – Part 11: Transport, storage and installation*.
Euro-code 3 – *Design of steel structures – Part 2: Steel bridge.*
BS 5400 1984: *Steel, concrete and composite bridges – Part 9: Bridge bearing.*
AASHTO/NSBA G9.1 – 2004, *Steel Bridge Bearing Design and Detailing Guidelines*.

11.4 General principle

11.4.1 **Function and types**. The bearings are located at the interface between the topside modules and the hull, their function being to minimise the structural interactions of the two bodies. Particularly, they shall reduce the bending moments in the hull module support frames as well as the tension, compression and torsion in the module primary girders. Additionally, fatigue effects will be significantly reduced on both module support frames and modules.

11.4.2 The focus of this Section is on elastomeric bearing pads which are extensively used in floating offshore installations. The bearings covered in this Section are shown in cases 1.1 to 1.8 of Table 1 of EN 1337-1.

11.5 Displacements

11.5.1 **Hull deformations and deflections**. The hull is subject to deformations and deflections resulting from:

- Longitudinal and transverse hull expansion and contraction.
- Longitudinal bending producing hogging and/or sagging.
- Axial torsion.

Hull hogging and sagging result in relative movement between the topside module, at the support nodes, and the module support frames. These relative movements may be caused by a combination of the following factors:

- Temperature variation between hull construction and hull operational conditions.
- Waves/environmental conditions.
- Variations to the distribution of topside and cargo loads along the vessel.

11.5.2 **The effect of displacement on bearings**. Horizontal displacements will induce rubber strain in elastomeric bearings, and will induce sliding upon PTFE/steel surfaces for pot bearings, while vertical displacements will induce compression or tension in both types. These effects must be considered in line with the bearing material's shear, tension and compression properties.

11.5.3 **Rotations for bearing design**. In the absence of detailed analysis, the bearings are to be designed for a minimum rotation of +/-0,5 degrees about both horizontal axes to ensure topside members satisfy the allowable deflection criterion of 1:300.

11.6 Serviceability, maintenance and protection requirements

11.6.1 Bearings under topside structures may be exposed to dirt, debris, oil and moisture that promote corrosion and deterioration. As a result, these bearings should be designed and installed to minimise environmental damage and to allow easy access for inspection. The service demands on bearings are very severe and result in a service life that is typically shorter than that of other structural elements. Therefore, allowance for bearing replacement should be given consideration in the design process and, where possible, lifting locations should be provided to facilitate removal and re-installation of bearings without damaging the structure. *See* EN 1337-9, 10 and 11 for specifications.

11.7 Additional requirements

11.7.1 **Design life**. The module bearings are required to be designed for the same service life as the module structures. The supplier of bearing material is to provide adequate evidence to support the design life of the bearings under the specified project's conditions.

11.7.2 **Environmental conditions**. The module bearings shall withstand the following environmental conditions:

- Air temperature.
- Humidity.
- Solar radiation.
- Flare radiation.
- Hydrocarbon/cryogenic spills.
- Salt-water spray.

The bearings could come into contact with miscellaneous hydrocarbons due to leakages occurring on the process equipments located on the modules. The supplier shall consider this potential event and ensure the proposed solution and supplied products do not jeopardise structural integrity or satisfactory system performance over the design life, in the event that this potential condition occurs.
However, bearing pads are not designed for blast, fire or cryogenic spills events. If necessary, a protection of bearing pads will be designed to ensure their integrity.
Passive fire protection of the bearings may be considered to protect pads against fire events.

11.7.3 Modules are to be constrained against excessive movement with lateral restraints, for example, horizontal stoppers for sliding bearings. Modules are also to be constrained against uplift unless it can be confirmed that uplift cannot occur. Consideration should be given to restricting the number of longitudinal supports to two to prevent transfer of vertical displacement of the hull to the module.

11.8 Bearing selection

11.8.1 Bearing selection is influenced by many factors, including loads, geometry, maintenance, available clearance, displacement, rotation, deflection, availability, policy, designer preference, construction tolerances and cost. In general, vertical displacements are restrained, rotations are allowed to occur as freely as possible, *see* 11.5.3, and horizontal displacements may be either accommodated or restrained. The reaction loads on each bearing are to be in accordance with the topside structural analysis and are to account for the worst scenario loading condition, taking the relative stiffness between the topsides and hull structure into account in the analysis, as appropriate.

11.8.2 Typically, steel stoppers are used with elastomeric bearings to transfer horizontal forces from topside to the substructure. The load transfer system between bearing plates and stoppers shall be carefully designed in order to minimise impact effects.

11.9 Elastomer

11.9.1 The shear stiffness of the bearing is its most important property because it affects the forces transmitted between the superstructure and substructure. Elastomers are flexible under shear and uniaxial deformation, but they are very stiff against volume changes. This feature makes possible the design of a bearing that is flexible in shear but stiff in compression.

11.9.2 Only neoprene for plain elastomeric bearing pads and steel-reinforced elastomeric bearings is recommended. All elastomers are visco-elastic, non-linear materials and, therefore, their properties vary with strain level, rate of loading and temperature. Bearing manufacturers evaluate the materials on the basis of international rubber hardness degrees (IRHD). However, this parameter is not considered to be a good indicator of the shear modulus '*G*'. The shear modulus '*G*' should not be taken less than 0,7 MPa (an IRHD not less than 50 or 55).

11.10 Fatigue

11.10.1 EN 1337 provides only test and design methods for repeated compression loadings. These should be followed in detail.

11.11 Detailing

11.11.1 Care should be taken for design of load transfer in fixed and sliding bearings. Sliding bearings should be designed according to EN1337-2. Maximum deflections under each loading case should be calculated considering non-linear behaviour. No gaps between bearing plates and stoppers are allowed. For common details, *see Steel Bridge Bearing Design and Detailing Guidelines*, AASHTO/NSBA G9.1 – 2004.

Watertight and Weathertight Integrity and Load Lines

Section 1 General

1.1 Application

1.1.1 This Chapter gives the minimum classification requirements for watertight and weathertight integrity and load line application.

1.1.2 The requirements for intact and damage stability and the assignment of load lines are to be in accordance with Pt 1, Ch 2,1.

1.1.3 The requirements in this Chapter may be modified where necessary to take into account the requirements of the appropriate National Administration responsible for the intact and damage stability of the unit.

1.1.4 For the purpose of this Chapter, the basic types of units are those defined in the *International Convention on Load Lines, 1966* (hereinafter referred to as the Load Line Convention), *see also* Pt 3 Ch 11,1.1 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Plans to be submitted

1.2.1 The following plans are to be submitted for approval:

- Deck drainage, scuppers and sanitary discharges.
- Ventilators and air pipes (including closing appliances).
- Watertight doors and hatch covers (internal and external) showing scantlings, coamings and closing appliances.
- Weathertight doors and hatch covers showing scantlings, coamings and closing appliances.
- Windows and side scuttles.
- Schematic diagrams of local and remote control of watertight and weathertight doors and hatch covers and other closing appliances.
- Location of control rooms.
- Freeing arrangements.

1.2.2 The following plans are to be submitted for information:

- General arrangement.
- Arrangement plan indicating the defined watertight boundaries of spaces included in the buoyancy.
- Arrangement plans of watertight doors and hatches.
- Details of intact and worst damage stability waterlines shown in elevations and plan views.
- Freeboard plan showing the maximum design operating draughts in accordance with Load Line Regulations and indicating the position of all external openings and their closing appliances.
- Location of down flooding openings.
- Trim and stability booklet, *see* Pt 1, Ch 2.

Section 2 Definitions

2.1 Freeboard deck

2.1.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part, and below which all openings in the sides of the unit are fitted with permanent means of watertight closing. For semi-submersible units, *see also* 5.2.4.

2.2 Freeboard

2.2.1 Freeboard is the distance measured vertically downwards amidships from the upper edge of the deck line to the upper edge of the related load line.

2.3 Weathertight

2.3.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the unit in any sea conditions.

2.3.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weathertight closing appliances.

2.4 Watertight

2.4.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

2.4.2 Generally, all openings below the freeboard deck in the outer shell boundaries and in main watertight decks and bulkheads are to be fitted with permanent means of watertight closing.

2.4.3 When the Rules require closing appliances with closely bolted covers, the pitch of the securing bolts is not to exceed five diameters.

2.5 Position 1 and Position 2

2.5.1 For the purpose of Load Line conditions of assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 – Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25L_L.

Position 2 – Upon exposed superstructure decks abaft the forward 0,25L_L.

where

L_L = the load line length in accordance with the *International Convention on Load Lines, 1966*.

2.5.2 The application to column-stabilised units will be specially considered, *see* 5.2.4.

2.6 Damage waterline

2.6.1 The damage waterline is the final equilibrium waterline after damage defined in the applicable stability Regulations, *see* 1.1.2.

2.7 Intact stability waterline

2.7.1 The intact stability waterline is the most severe inclined waterline to satisfy the range of intact stability defined in the applicable stability Regulations, *see* 1.1.2.

2.8 Down flooding

2.8.1 Down flooding means any flooding of the interior of any part of the buoyant structure of a unit through openings which cannot be closed watertight or weathertight, as appropriate, in order to meet the intact or damage stability criteria or which are required for operational reasons to be left open.

2.8.2 The down flooding angle is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

2.8.3 Intact stability is to comply with Pt 1, Ch 2,1.

■ *Section 3* Installation layout and stability

3.1 Control rooms

3.1.1 Control rooms essential for the safe operation of the unit in an emergency are to be situated above zones of immersion after damage, as high as possible and as near a central position on the unit as is practicable. The requirements for the central ballast control station on column-stabilised units are to be in accordance with Pt 6, Ch 1,2.8.

3.2 Damage zones

3.2.1 The extent of defined damage is to be in accordance with the applicable damage stability Regulations.

3.2.2 All piping, ventilation ducts and trunks, etc., should, where practicable, be situated clear of the defined damage zones. When piping, ventilation ducts and trunks, etc., are situated within the defined extent of damage, they are to be assumed damaged and positive means of closure are to be provided at watertight subdivisions to preclude progressive flooding of other intact spaces, *see also* Pt 5, Ch 13,2 of the Rules for Ships.

3.2.3 In addition to the defined damages referred to in 3.2.1, compartments with a boundary formed by the bottom shell of the unit are to be considered flooded individually unless agreed otherwise with LR.

■ *Section 4* Watertight integrity

4.1 Watertight boundaries

4.1.1 All units are to be provided with watertight bulkheads, decks and flats to give adequate strength and the arrangements are to suit the requirements for subdivision, floodability and damage stability. In all cases, the plans submitted are to clearly indicate the location and extent of the bulkheads. In the case of column-stabilised drilling units, the scantling of the watertight flats and bulkheads are to be made effective to that point necessary to meet the requirements of damage stability and are to be indicated on the appropriate plans.

4.1.2 The number and disposition of watertight bulkheads are to comply with Ch 3,5.

4.1.3 The strength of watertight subdivisions are to comply with Ch 6,7.

4.1.4 Ship units and other surface type units are to be fitted with a collision bulkhead in accordance with Pt 3, Ch 3,4.2 of the Rules for Ships.

4.2 Tank boundaries

4.2.1 Deep tanks for fresh water, fuel oil or any other tanks which are not normally kept filled in service are, in general, to have wash bulkheads or divisions.

4.2.2 Tank bulkheads and watertight divisions are to have adequate strength for the maximum design pressure head in normal operating and damage conditions and the scantlings are to comply with Ch 6,7.

4.3 Boundary penetrations

4.3.1 Where internal boundaries are required to be watertight to meet damage stability requirements, the number of openings in such boundaries is to be reduced to the minimum compatible with the design and proper working of the unit.

4.3.2 Where piping, including air and overflow pipes, ventilation ducts, shafting, electric cable runs, etc., penetrate watertight boundaries, arrangements are to be made to ensure the watertight integrity of the boundary. Details of the arrangements are to be submitted for approval.

4.3.3 No openings such as manholes, watertight doors, pipelines or other penetrations are to be cut in the collision bulkhead of ship units and other surface type units, except as permitted by Pt 5, Ch 13,3 and 4 of the Rules for Ships.

4.3.4 Where pipelines or ducts serve more than one compartment, satisfactory arrangements are to be provided to preclude the possibility of progressive flooding through the system to other spaces in the event of damage, *see also* 3.2.

4.3.5 Where piping systems and ventilation ducts are designed to watertight standards and are suitable for the maximum design pressure head in damage conditions, they are to be provided with valves at the boundaries of each watertight compartment served.

4.3.6 Ventilation ducts which are of non-watertight construction are to be provided with valves where they penetrate watertight subdivision boundaries.

4.3.7 Where valves are provided at watertight boundaries to maintain watertight integrity in accordance with 4.3.5 and 4.3.6, these valves are to be capable of being operated from a pump-room or other normally manned space, a weather deck, or a deck which is above the final waterline after flooding. In the case of a column-stabilised unit, this would be the central ballast control station. Valve position indicators should be provided at the remote control station, weather deck or a normally manned space.

4.3.8 For self-elevating units, the ventilation system valves required to maintain watertight integrity should be kept closed when the unit is afloat. Necessary ventilation in this case should be arranged by alternative approved methods.

4.4 Internal openings related to damage stability

4.4.1 The requirements for the operation, alarm displays and controls of watertight doors and hatch covers and other closing appliances are given in Pt 7, Ch 1,9.

4.4.2 Internal access openings fitted with appliances to ensure watertight integrity, are to comply with the following:

(a) Watertight doors and hatch covers which are used during the operation of the unit while afloat may normally be open, provided the closing appliances are capable of being remotely controlled from a damage central control room on a deck which is above any final waterline after flooding and are also to be operable locally from each side of the bulkhead. Open/shut indicators are to be provided in the control room showing whether the doors are open or closed. In addition, remotely operated doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors with audible alarm. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimising the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism. It shall be possible to open/close the door by hand at the door itself from both sides.

(b) Doors or hatch covers in self-elevating units or doors placed above the deepest load line draft in column-stabilised and surface units, which are normally closed while the unit is afloat may be of the quick acting type and should be provided with an alarm system (e.g., light signals) showing personnel both locally and at the central ballast control station whether the doors or hatch covers in question are open or closed. A notice should be affixed to each such door or hatch cover stating that it is not to be left open while the unit is afloat.

(c) The closing appliances are to have strength, packing and means for securing which are sufficient to maintain watertightness under the maximum design water pressure head of the watertight boundary under consideration.

4.4.3 Internal openings fitted with appliances to ensure watertight integrity, which are to be kept permanently closed while afloat, are to comply with the following:

(a) A notice to the effect that the opening is always to be kept closed while afloat is to be attached to the closing appliances in question.

(b) Opening and closing of such closing appliances are to be noted in the unit's logbook, or equivalent.

(c) Manholes fitted with gaskets and closely bolted covers need not be dealt with as under (a).

(d) The closing appliances are to have strength, packing and means for securing which are sufficient to maintain watertightness under the maximum water pressure head of the watertight boundary under consideration.

4.5 External openings related to damage stability

4.5.1 Where watertight integrity is dependent on external openings which are used during the operation of the unit while afloat, they are to comply with the following:

(a) The lower edge of openings of air pipes (regardless of their closing appliances) is to be above the final equilibrium damage waterline including wind heel effects.
(b) The lower edge of ventilator openings, doors and hatches with manually operated means of weathertight closures is to be above the final equilibrium damage waterline including wind heel effects.
(c) Openings such as manholes, fitted with gaskets and closely bolted covers, and side scuttles and windows of the non-opening type with inside hinged deadlights which are fitted with appliances to ensure watertight integrity, may be submerged. Such openings are not allowed to be fitted in the column of stabilised units.
(d) Scuppers and discharges are to be fitted with closing appliances, *see* 10.1.
(e) Where flooding of chain lockers or other buoyant volumes may occur, the openings to these spaces should be considered as downflooding points.

4.5.2 Where watertight integrity is dependent upon external openings which are permanently closed during the operation of the unit while afloat, such openings are to comply with the requirements of 4.4.3.

4.5.3 External watertight doors and hatch covers of limited size which are used while afloat may be accepted below the worst damage waterline, including wind heel effects, provided they are on or above the freeboard deck and the closing appliances comply with the requirements of 4.4.2(a) and (b).

4.6 Strength of watertight doors and hatch covers

4.6.1 The symbols used in this sub-Section are as follows:

d = distance between securing devices, in metres

$f_1 = 1,1 - \dfrac{s}{2500 l_s}$ but not greater than 1

h_D = design pressure head, in metres, measured vertically from the bottom of the door to the worst damage waterline plus 5 m

k = higher tensile steel factor as defined in Ch 2,1.2

l_s = span of stiffener between support points, in metres

s = spacing of stiffeners, in mm

P_I = packing line pressure along edges, in N/cm (kgf/cm), but not less than 50 (5,1).

4.6.2 Closing appliances for internal and external openings are to have scantlings in accordance with this sub-Section and are to satisfy the requirements of 4.4 and 4.5 respectively.

4.6.3 In general, watertight closing appliances are to be designed to withstand the design pressure head from both sides of the appliance unless the mode of failure based on the damage stability criteria can only result in one-sided pressure loading.

4.6.4 The thickness of plating, t, subjected to lateral pressure in damage conditions is to be not less than:

$t = 0{,}0048 s f_1 \sqrt{h_D k}$ mm but not less than 8 mm.

4.6.5 The section modulus, z, of panel stiffeners fitted in one direction and edge stiffeners is not to be less than:

$z = 0{,}0065 s\, k\, h_D\, l_s^2$ cm^3 but not less than 15 cm^3

The section modulus of secondary panel stiffeners may also be determined from the above formula, but doors with stiffeners designed as grillages will be specially considered.

4.6.6 The moment of inertia, I, of edge stiffeners is in general not to be less than:

$I = 0{,}8 P_I d^4$ cm^4 $(8 P_I d^4$ cm$^4)$

4.6.7 Securing devices for closing appliances are to be designed for water pressure acting on the opposite side of the appliance to which they are positioned, *see also* 4.6.3.

4.6.8 The strength of the bulkhead and deck framing in way of watertight closing appliances is to comply with the requirements of Ch 6,7.

4.6.9 Watertight closing appliances are to be hydraulically tested in accordance with the requirements of Table 1.8.1 in Pt 3, Ch 1,8 of the Rules for Ships. In general, the test is to be carried out before the appliance is fitted to the unit. The test pressure is to be applied separately to both sides of the appliance, *see also* 4.6.3.

4.6.10 After installation in the unit, watertight closing appliances are to be hose tested in accordance with the requirements of Table 1.8.1 in Pt 3, Ch 1,8 of the Rules for Ships, and functional tests are to be carried out to verify the satisfactory operation of the appliance, its control and alarm functions, as required by Pt 7, Ch 1,9.

4.7 Weathertight integrity related to stability

4.7.1 Any opening, such as an air pipe, ventilator, ventilation intake or outlet, non-watertight sidescuttle, small hatch, door, etc., having its lower edge submerged below a waterline associated with the zones indicated in (a) or (b), is to be fitted with a weathertight closing appliance to ensure the weathertight integrity, when:

(a) A unit is inclined to the range between the first intercept of the right moment curve and the wind heeling moment curve and the angle necessary to comply with the requirements of 3.3 of the 2009 IMO MODU Code during the intact condition of the unit while afloat; and
(b) A column-stabilised unit is inclined to the range:
    (i) Necessary to comply with the requirements of 4.7.1(a) and 5.2.6 and with a zone measured 4,0 m perpendicularly above the final damaged waterline per 3.4.3 of the 2009 IMO MODU Code referred to Fig. 7.4.1, and

(ii) Necessary to comply with the requirements of 3.4.4 of the 2009 IMO MODU Code.

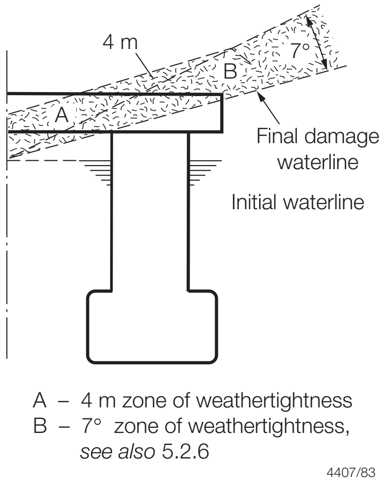


Fig. 7.4.1
Minimum weathertight integrity requirements for column-stabilised and tension-leg units

4.7.2 External openings fitted with appliances to ensure weathertight integrity, which are kept permanently closed while afloat, are to comply with the requirements of 4.4.3(a) and (b).

4.7.3 External openings fitted with appliances to ensure weathertight integrity, which are secured while afloat are to comply with the requirements of 4.4.2(a) and (b).

■ *Section 5*
Load lines

5.1 General

5.1.1 Any unit to which a load line is required to be assigned under the applicable terms of the Load Line Convention is to be subject to compliance with the Convention, *see* 1.1.2. For semi-submersible and self-elevating units, *see also* 5.2 and 5.3 respectively.

5.1.2 The requirements of the Load Line Convention, with respect to weathertightness and watertightness of decks, superstructures, deckhouses, doors, hatchway covers, other openings, ventilators, air pipes, scuppers, inlets and discharges, etc., are taken as a basis for all units in the afloat conditions.

5.1.3 The requirements for hatchways, doors and ventilators are dependent upon the position on the unit as defined in 2.5.

5.1.4 Units which cannot have freeboard computed by normal methods laid down by the Load Line Convention will have the permissible draughts determined on the basis of meeting the applicable intact stability, damage stability and structural requirements for transit and operating conditions while afloat. In no case is the draught to exceed that permitted by the Load Line Convention, where applicable.

5.1.5 All units are to have load line marks which designate the maximum permissible draught when the unit is in the afloat condition. Such markings are to be placed at suitable visible locations on the structure, to the satisfaction of LR. These marks, where practicable, are to be visible to the person in charge of mooring, lowering or otherwise operating the unit.

5.2 Column-stabilised units and tension-leg units

5.2.1 Load lines for column-stabilised and tension-leg units are to be based on the following:
- The strength of the structure.
- The air gap between the maximum operating waterline and the bottom of the upper hull structure.
- The intact and damage stability requirements.

5.2.2 The conditions of assignment are to be based on the requirements of the Load Line Convention. The Regulations of the relevant National Administration are also to be complied with, *see* 1.1.2.

5.2.3 In general, the heights of hatch and ventilator coamings, air pipes, door sills, etc., in exposed positions and all closing appliances are to be determined by consideration of both intact and damage stability requirements.

5.2.4 The freeboard deck and reference deck from which the air gap is measured, is normally taken as the lowest continuous deck exposed to weather and sea, and which has permanent means of closing and below which all openings are watertight and permanently closed at sea.

5.2.5 Side scuttles and windows, including those of non-opening type, or other similar openings, are not to be fitted below the freeboard deck, as defined in 5.2.4.

5.2.6 In addition to the stability requirements in 4.7, the upper deck and the boundaries of the enclosed upper hull structure between the upper deck and the freeboard deck are to be made weathertight.

5.2.7 Special consideration will be given to the position of openings which cannot be closed in emergencies, such as air intakes for emergency generators.

5.3 Self-elevating units

5.3.1 Load lines and conditions of assignment for self-elevating units when afloat in transit conditions will be subject to the applicable terms of the Load Line Convention. A load line, where assigned, is not applicable to self-elevating units when resting on the sea bed, or when lowering to or raising from such position. The Regulations of the relevant National Administration are also to be complied with, *see* 1.1.2.

5.3.2 Special consideration is to be given to the freeboard of units with moonpools or drilling wells extending through the main hull structure.

5.3.3 In general, the heights of hatch and ventilator coamings, air pipes, door sills, etc., in exposed positions and all closing appliances are also to be determined by consideration of both intact and damage stability requirements.

5.4 Ship units and surface type units

5.4.1 Ship units and surface type units are to comply with the requirements of 5.1.1. Special consideration is to be given to the freeboard of units with moonpools or drilling wells extending through the main hull structure.

5.5 Sea bed-stabilised units

5.5.1 When afloat in transit conditions, sea bed-stabilised units are to comply with the requirements of 5.2 and 5.3 as applicable.

5.6 Deep draught caissons and buoy units

5.6.1 The weathertight integrity of units which are not subject to the requirements of the Load Line Convention will be specially considered on the basis of 5.7 and the requirements for both intact and damage stability. *See also* 1.1.

5.7 Weathertight integrity

5.7.1 Closing arrangements for shell, deck and bulkhead openings and the requirements for ventilators, air pipes and overboard discharges, etc., are to comply with Sections 6 to 10.

5.7.2 The requirements of this Chapter conform, where relevant, with those of the Load Line Convention. Reference should also be made to any additional requirements of the National Authority of the country in which the unit is to be registered and to the appropriate Regulations of the Coastal State Authority in the area where the unit is to operate.

5.7.3 The closing appliances are, in general, to have a strength at least corresponding to the required strength of that part of the hull in which they are fitted.

5.7.4 The requirements for closing appliances of hatches, doors, ventilators, air pipes, etc., and their associated coamings, situated at such a height as will not constitute a danger to the weathertightness of the unit, will be specially considered.

5.7.5 In all areas where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

■ *Section 6*
Miscellaneous openings

6.1 Small hatchways on exposed decks

6.1.1 The requirements of Pt 3, Ch 11,6.1 of the Rules for Ships are to be complied with, as applicable.

6.1.2 In general, small hatch cover scantlings and securing devices are to be in accordance with Table 7.6.1 or with an acceptable standard.

6.1.3 Hatch covers of a greater size than those defined in Table 7.6.1 will have their scantlings and closing arrangements specially considered.

Table 7.6.1 Hatch cover scantlings

Size of hatch (mm)	Plate (mm)	Stiffeners	Toggles
600 x 600	8,0	—	4
760 x 760	8,0	—	6
925 x 925	8,0	75 x 7,5 mm flat bar	7
1220 x 1220	10,0	75 x 7,5 mm flat bar	8

6.1.4 When applicable, large hatch covers are to comply with the requirements of Pt 3, Ch 11 of the Rules for Ships.

6.1.5 Small hatches, including escape hatches, are to be situated clear of any obstructions.

6.1.6 The height and scantlings of coamings are to be in accordance with 6.3.

6.2 Hatchways within enclosed superstructures or ‘tween decks

6.2.1 The requirements of 6.1 are to be complied with, where applicable.

6.2.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.3 Hatch coamings

6.3.1 The height of coamings of hatchways situated in Positions 1 and 2 closed by steel covers fitted with gaskets and clamping devices are to be not less than:

- 600 mm at Position 1;
- 450 mm at Position 2.

6.3.2 Lower heights than those defined in 6.3.1 may be considered in relation to operational requirements and the nature of the spaces to which access is given.

6.3.3 Coamings with height less than given in 6.3.1 may normally be accepted for column-stabilised and tension-leg units after special consideration, *see also* 6.3.4.

6.3.4 Coaming heights on all units are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

6.3.5 The thickness of the coamings is to be not less than the minimum thickness of the structures to which they are attached, or 11 mm, whichever is the lesser. Stiffening of the coaming is to be appropriate to its length and height. Scantlings of coamings more than 900 mm in height will be specially considered.

6.4 Manholes and flush scuttles

6.4.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.5 Companionways, doors and access arrangements on weather decks

6.5.1 The requirements of Pt 3, Ch 11,6.4 of the Rules for Ships are to be complied with, as applicable.

6.5.2 For access to spaces in the oil storage area on units with tanks for the storage of oil in bulk, *see* Pt 3, Ch 3,2.11.

6.5.3 The height of doorway sills above deck sheathing, if fitted, is to be not less than 600 mm in Position 1, and not less than 380 mm in Position 2. For semi-submersible units, *see* 5.2.3.

6.5.4 Doorway sill heights on all units are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

6.5.5 On ship units and other surface type oil storage units, direct access from the freeboard deck to the machinery space through exposed casings is not permitted, except when 6.5.6 applies. A door complying with 6.5.3 may, however, be fitted in an exposed machinery casing on these units, provided that it leads to a space or passageway which is of equivalent strength to the casing and is separated from the machinery space by a second weathertight door complying with 6.5.3. The outer and inner weathertight doors are to have sill heights of not less than 600 mm and 230 mm respectively and the space between is to be adequately drained by means of a screw plug or equivalent.

6.5.6 For ship units and other surface type oil storage units with freeboards greater than, or equal to, a Type B ship (as defined in the Load Line Convention), inner doors are not required for direct access to the engine room.

6.6 Side scuttles, windows and skylights

6.6.1 For ship units and other surface type units and self-elevating units, when afloat, the requirements of Pt 3, Ch 11,6.5 of the Rules for Ships are to be complied with, as applicable.

6.6.2 A plan showing the location of side scuttles and windows is to be submitted. Attention is to be given to any relevant Statutory Requirements of the Coastal State Authority where the unit is to operate and/or the National Authority of the country in which the unit is to be registered.

6.6.3 The location of windows and side scuttles and the provision of deadlights or storm covers on semi-submersible units will be specially considered in each case, *see also* 4.5.1(c) and 5.2.5.

6.6.4 Windows and side scuttles are to be of the non-opening type where damage stability calculations indicate that they would become immersed as a result of specified damage.

■ *Section 7*
Tank access arrangements and closing appliances in oil storage units

7.1 General

7.1.1 The requirements of Pt 3, Ch 11,7 of the Rules for Ships are to be complied with, as applicable.

7.1.2 The height of coamings may be required to be increased if this is shown to be necessary by damage stability regulations.

7.1.3 Access openings are to have smooth edges and edge stiffening is also to be arranged in regions of high stress.

7.1.4 Small openings are to be kept clear of other access openings.

7.1.5 The general requirements for access to spaces within the oil storage area are to comply with Pt 3, Ch 3,2.11.

■ *Section 8* Ventilators

8.1 General

8.1.1 The requirements of Pt 3, Ch 12,2 of the Rules for Ships are to be complied with, as applicable.

8.1.2 Ventilators from deep tanks and tunnels passing through pontoons, columns and 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

8.1.3 Ventilator coaming heights and closing appliances on all units are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

8.1.4 On self-elevating units, it is recommended that closing appliances for ventilators situated on the freeboard deck are fitted at or below the deck level.

8.1.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw-down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm on self-elevating units. On self-elevating units, a notice indicating 'keep closed while unit is afloat' is to be attached to the head.

8.1.6 A ventilator head not forming part of the closing arrangements is to be not less than 5,0 mm thick on column-stabilised units and 6,5 mm thick on other units.

8.1.7 Wall ventilators (jalousies) may be accepted, provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles, or equivalent arrangements provided.

8.1.8 Fire dampers are not acceptable as ventilator closing appliances unless they are of substantial construction, gasketed, and able to be secured weathertight in the closed position.

8.1.9 Reference should be made to 8.1.3 concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with Pt 3, Ch 12,2.3.1 of the Rules for Ships.

■ *Section 9* Air and sounding pipes

9.1 General

9.1.1 The requirements of Pt 3, Ch 12,3 of the Rules for Ships and Pt 5, Ch 13,12 of the Rules for Ships are to be complied with, as applicable.

9.1.2 Air pipes are generally to be led to an exposed deck and are to be well protected from mechanical damage.

9.1.3 Air pipes are also to satisfy the requirements for intact and damage stability, *see* 4.5 and 4.7.

9.1.4 All openings of air and sounding pipes are to be provided with approved automatic type closing appliances which prevent the free entry of water and excessive pressure imposed on the tank.

9.1.5 Pressure/vacuum valves as required by Pt 5, Ch 15 may be accepted as closing appliances for oil storage tanks.

■ *Section 10* Scuppers and sanitary discharges

10.1 General

10.1.1 The requirements of Pt 3, Ch 12,4 of the Rules for Ships are to be complied with, as applicable.

10.1.2 The additional requirements contained within this Section are applicable to semi-submersible and self-elevating units only.

10.1.3 Normally, each separate overboard discharge from an enclosed space is to be fitted with an automatic non-return valve at the shell boundary. Where the inboard end of a discharge is situated below the worst damage water line, the non-return valve is to be of a type which is effective at the worst expected inclination after damage, whatever the orientation, and is to have a positive means of closing, operable from a readily accessible position above the damage water line. An indicator is to be fitted at the control position showing whether the valve is open or closed.

10.1.4 The requirements for non-return valves are applicable only to those discharges which remain open while the unit is afloat during normal operation. For discharges which are closed while the unit is afloat, such as gravity drains from tanks, a single screw-down valve operated from the freeboard deck is considered to provide sufficient protection. An indicator is to be fitted at the control position showing whether the valve is open or closed.

10.1.5 The non-return valve required by 10.1.3 is to be mounted directly on the shell and secured in accordance with Pt 5, Ch 13,2.4 of the Rules for Ships. If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell.

10.1.6 Discharge piping, situated between the sea level and the bottom of the upper hull of semi-submersible units and below the bottom shell of the self-elevating units when in the elevated position, is to be of substantial construction, well secured and protected.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all unit types and components.

1.1.2 Requirements are given in this Chapter for the following:

(a) Welding connection details, defined practices and sequence, consumables and equipment, procedures, workmanship and inspection.
(b) End connection scantlings and constructional details for longitudinals, beams, frames and bulkhead stiffeners.
(c) Primary member proportions, stiffening and construction details.

1.1.3 All units are to comply with the requirements of Pt 3, Ch 10 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), as applicable to the type of unit. Additional requirements as indicated in the following Sections should also be complied with, as applicable.

1.2 Symbols

1.2.1 Symbols are defined as necessary in each Section.

■ *Section 2* Welding

2.1 General

2.1.1 Requirements for welding are given in Chapter 12 and Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and general requirements for hull construction are also given in Pt 3, Ch 10,2 of the Rules for Ships.

2.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

2.2 Impact test requirements

2.2.1 Charpy V-notch impact tests are to be carried out in the weld metal, fusion line and heat affected zone in accordance with 2.2.2 to 2.2.4.

2.2.2 For special structure, the impact test temperature and minimum absorbed energy for the weld and heat affected zone are to be the same as that specified for the base materials being welded.

2.2.3 For primary and secondary structure, the impact test temperature and the minimum absorbed energy for the weld metal and heat affected zone are to be in accordance with the requirements of the material grade being welded, as specified in Table 12.2.2 in Chapter 12 of the Rules for Materials.

2.2.4 Fabrications whose thickness exceeds 65 mm are, in general, to be subjected to a post weld heat treatment. Impact tests are required to be made on specimens heat treated in the same manner as the actual construction. The absorbed energy is to be in accordance with 2.2.2 and 2.2.3; however, the test temperatures may be 10°C higher.

2.3 Workmanship and inspection

2.3.1 Checkpoints examined at the construction stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the Builder. The locations and numbers of checkpoints are to be agreed between the Builder and the Surveyor. Special attention is to be paid to the welded connections of primary bracings and their end connections and other structure defined as special in Ch 2,2.

2.3.2 Additional locations for NDE for ship units and other surface type units are shown in Table 8.2.1.

2.3.3 Typical locations for NDE and the recommended number of checkpoints to be taken in column-stabilised and self-elevating units are shown in Table 8.2.2. For other unit types, the extent of NDE will be specially considered in each case. Critical locations as identified by LR's *ShipRight Fatigue Design Assessment* and other relevant fatigue calculations are also to be considered, where applicable. A document detailing the proposed items to be examined is to be submitted by the Builder for approval.

2.3.4 For the hull structure of units designed to operate in low air/sea temperatures, the recommended extent of non-destructive examination will be specially considered.

2.3.5 All NDE is to be performed in accordance with the requirements specified in Ch 13,2 of the Rules for Materials.

2.3.6 In general, fabrication tolerances are to comply with Section 6. It is important to ensure that compatibility exists between design calculations and construction standards, particularly in fatigue sensitive areas.

Table 8.2.1 Additional non-destructive examination of welds on surface type units (as applicable)

Recommended extent of testing, *see* Note 1 General, *see* Notes 8 and 9		
Structural item	Location	Checkpoints, *see* Note 1
Penetrations and attachments to hull, e.g., sea inlets, piping, anode supports	Throughout	100%
Moonpool integration structure	Throughout	*See* Notes 2 and 4
Topside support structure connections to hull and hull structure in way	Throughout	25%, *see* Notes 4 and 5
Flare stack and crane pedestal structure	Throughout	50%, *see* Notes 4 and 5
Connections to deck	Local	100%
Other structural items	Throughout	*See* Notes 3 and 4
Side shell butts, seams and intersection welds where vessel is strengthened for operations in ice	Forward end Remainder	*See* Note 6 *See* Note 7
Exposed shell butts, seams and intersection welds where vessel is designed for low temperature operations	Throughout	*See* Note 7
Local areas identified as fatigue sensitive, e.g.: • Identified bracket connections at intersections of side shell longitudinals and transverse frames and bulkheads • Key locations identified on moonpool integration structure • Topside support stool welds to upper deck and underdeck welds in way • Flare stack support welds to upper deck and underdeck welds in way	 Local Local Local Local	 *See* Note 3 100% 100% 100%
Other items	Local	*See* Notes 3 and 4

NOTES
1. The diameter of each checkpoint is to be between 0,3 and 0,5 m, and volumetric and magnetic particle checks are to be carried out unless indicated otherwise.
2. 10% selection of butts and seams and 20% at intersections. Particular attention is to be given in way of stops and starts of automatic and semi-automatic welding during fabrication.
3. Random selection to the Surveyor's satisfaction.
4. Particular attention is also given to ends of bracket connections where fitted.
5. Particular attention to be given in way of weld intersections and discontinuities at stop and start positions.
6. 10% of butts and seams and 30% at intersections. Particular attention to be taken in way of stops and starts of automatic and semi-automatic welding during fabrication.
7. 10% selection of butts and seams and 25% at intersections. Particular attention to be given in way of stops and starts of automatic and semi-automatic welding during fabrication.
8. Agreed locations are not to be indicated on blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
9. Particular attention is to be given to repair rates. Additional welds are to be tested in the event that defects such as lack of fusion or incomplete penetration are repeatedly observed.

Table 8.2.2 Non-destructive examination of welds on column-stabilised and self-elevating units

Recommended extent of testing, *see* Note 9 General, *see* Note 1		
Structural item	Volumetric checkpoints	Magnetic particle checkpoints
Bracing butt and seam welds	100%	100%
Bracing weld connections to: • columns • pontoons • upper hull • lower nodes	100%	100%
Attachments to legs and bracings	—	100%
Penetrations through legs and bracings	100%	100%
Bracing shell attachment of diaphragms, gussets, stiffeners	100%	100%
Column shell butts and seams	*See* Note 4	20%
Column weld connections to: • pontoons • upper hull • in way of anchor fairleads and sheaves	100%	100%
Internal column structure connections	5%, *see* Note 5	*See* Note 3
Pontoons, hull, shell and bulkhead butts/seams	*See* Note 4	20%
Leg footings or mats	*See* Note 4	20%
Internal pontoon structure	5%, *see* Note 5	*See* Note 3
Hull penetrations, sub-sea inlets, anode and attachments, piping connection supports, etc.	100%	—
Bilge keel butts	100%	100%
Self-elevating unit leg connections • leg chords • leg trusses • leg attachments to footings or mats • butts and seams in chords and trusses	100%	100%
Upper hull: Main bulkheads/deck girders	*See* Notes 2 & 4	*See* Note 6
Strength decks and drill floor	*See* Notes 2 and 4	*See* Note 7
In way of windlasses and mooring winches	—	100%
Topside support structure connections to deck	25%	25%
Flare stack, crane pedestals and gusset connections to deck	100%	100%
Drill floor, derrick substructure and moonpool structure	*See* Notes 4 and 7	*See* Note 7
Helideck primary support, cantilevered life boat platform primary support	20%	20%
Helideck and lifeboat platform remainder	*See* Note 8	—
Other items	*See* Note 8	*See* Note 8

NOTES
1. Back-up structure of the items in question is also to be included, where applicable.
2. 100% in way of full penetration welding at end of diaphragm plates, gussets, stiffeners, etc.
3. 50% in way of fillet welds around stiffener ends, notches, cut-outs, drain hole openings, etc.
4. 10% selection of butts and seams and 20% at intersections. Particular attention to be taken in way of stops and starts of automatic and semi-automatic welding during fabrication.
5. 10% random selection of butt welds, of pontoon and column shell longitudinal stiffeners and transverse and longitudinal bulkheads stiffeners.
6. 10% random selection of fillet welds in way of stiffener ends, drain hole openings, cut-outs, notches, etc.
7. Girder and sub-structure butt welds 100% UT; principal connections to deck and main structure 100% UT and 100% MPI.
8. Random spot checks to the Surveyor's satisfaction.
9. The diameter of each checkpoint is to be between 0,3 and 0,5 m.

2.4 Fillet welds

2.4.1 Additional weld factors for structure not specifically covered by the Rules for Ships are given in Table 8.2.3.

Table 8.2.3 Additional weld factors

Item	Weld factor	Remarks
(1) General application:		
(a) Shell boundaries of columns to lower and upper hulls	full penetration	except as required below
(b) Internal watertight or oiltight plate boundaries	0,34	generally, but alternative proposals will be considered in specific areas
(2) (a) Upper hull framing and hull framing on self-elevating units:		
(i) Webs of web frames and stringers:		
• to shell	0,16	
• to face plate	0,13	
(ii) Tank side brackets to shell and inner bottom	0,34	
(b) Primary hull framing and girders on lower hulls, columns and caissons of column-stabilised units		to be in accordance with the Rules for Ships
(3) Decks and supporting structure: Primary deck girders and connections between primary members on column-stabilised units		generally to comply with the Rules for Ships, but full penetration welding may be required
(4) Self-elevating units:		
(a) Leg construction, general	full penetration	
(b) Leg connections to footings or mats	full penetration	
(c) Internal webs, girders and bulkheads in footings and mats	0,44	full penetration may be required
(d) Internal stiffeners in footings and mats	0,34	
(e) Jackhouses, general	0,44	full penetration may be required
(f) Bulkheads and primary structures in way of leg wells	0,44	full penetration may be required
(5) Main bracings and 'K' joints, etc.:		
(a) Ring frames, girders and stiffeners	full penetration	generally, but alternative proposals may be considered
(b) Shell boundaries and end connections including brackets, gussets and cruciform plates	full penetration	
(6) Miscellaneous structures, fittings and equipment:		
(a) Rings and coamings for manhole type covers to shell on stability columns and lower hulls	full penetration	generally, but alternative proposals may be considered
(b) Rings for manhole type covers, to deck or bulk head	0,34	
(c) Frames of watertight and weathertight bulk head doors	0,34	
(d) Stiffening of doors	0,21	
(e) Ventilator, air pipes, etc., coamings to deck	0,34	Load line positions 1 and 2
(f) Ventilator, etc., fittings	0,21	elsewhere
(g) Scuppers and discharges, to deck	0,44	
(h) Masts, flare structures, derrick posts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
(j) Deck machinery seats to deck	0,21	generally
(k) Mooring equipment seats and fairleads	0,44	full penetration welding may be required
(l) Bulwark stays to deck	0,21	
(m) Bulwark attachment to deck	0,34	
(n) Guard rails, stanchions, etc., to deck	0,34	
(o) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(p) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
(q) Fabricated anchors	full penetration	
(r) Turret and swivel supports	0,44	full penetration welding may be required
(s) Process plant stools to deck	0,44	full penetration welding may be required

2.4.2 Continuous welding is to be adopted in the following locations:

(a) All weldings inside tanks and peak compartments.
(b) Primary and secondary members to shell in lower hulls and stability columns.
(c) Primary and secondary members to main bracings, trusses or 'K' joints.

2.5 Welding of tubular members

2.5.1 Welding is to comply with agreed Internationally or Nationally accepted Codes such as AWS or API and all welding generally is to conform to the following:

(a) All steel is to be joined by complete penetration groove welds.
(b) Unless single sided welding has been agreed for the particular weld configuration, double sided welds are to be used, wherever practicable.
(c) In lattice type structures, a minimum weld attachment length at the cord of 1,5 times the brace wall thickness is required at all locations. This is based on fatigue considerations.
(d) Care is to be taken to ensure the weld surface profile is smooth and blends with the parent material.
(e) Backing strips are not to be used unless specially agreed with LR.
(f) Root gaps are to be generally in the range of 3 to 6 mm.
(g) Bevels are to be such that the included angle is in the range 45° to 60°. However, when the dihedral angle is less than 45°, the included angle may be reduced as indicated for locations 4 and 5, *see* Fig. 8.2.2.
(h) Where saddle weld toe grinding has been agreed as a method of improving fatigue life, at the locations agreed, the grinding of the weld toe is to produce a smooth transition between the weld and the parent plate. The grinding should remove all defects, slag inclusions and any undercut. Overgrinding into the parent plate is not to exceed 2 mm or 0,05 times the plate thickness, whichever is less. The grinding tool should preferably have a spherical head (e.g., a tungsten carbide burr) and, in general, disc-grinders are to be avoided except for initial heavy grinding. Any marks made by rotation of the grinding tool are to be aligned with the direction of stress. The surface of the main body of the weld may be dressed to produce a better concave profile if the as-welded profile is poor, *see* Fig. 8.2.1 and Fig. 8.2.8. Care must be exercised in order that overgrinding does not excessively reduce the size of the attachment weld and in no case less than that required by the Rules.

2.5.2 Locations 1, 2, 3, 4 and 5 are related to the local dihedral angle (the angle between the brace wall and chord wall). Transition from one detail to another is to be by gradual uniform level preparation and surface profile, *see* Fig. 8.2.2.

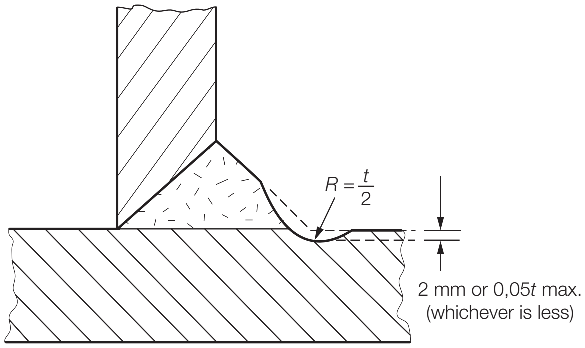


Fig. 8.2.1 Grinding of weld toe

Location	Applicable range of local dihedral angle ψ	Fig. No.
1	180° — 135°	8.2.3
2	150° — 90°	8.2.4
3	90° — 50°	8.2.5
4	75° — 30°	8.2.6
5	40° — 15°	8.2.7

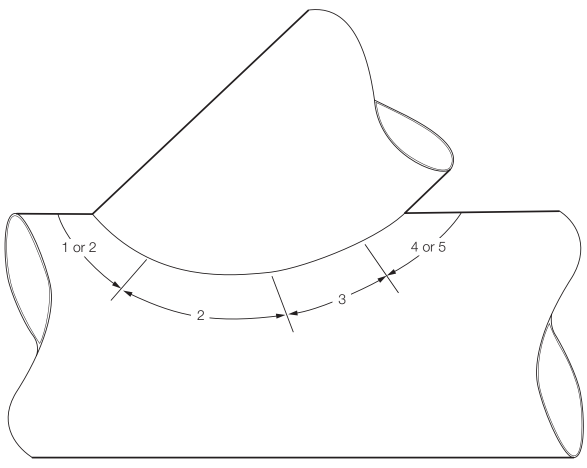


Fig. 8.2.2
Local dihedral angle for weld profile locations

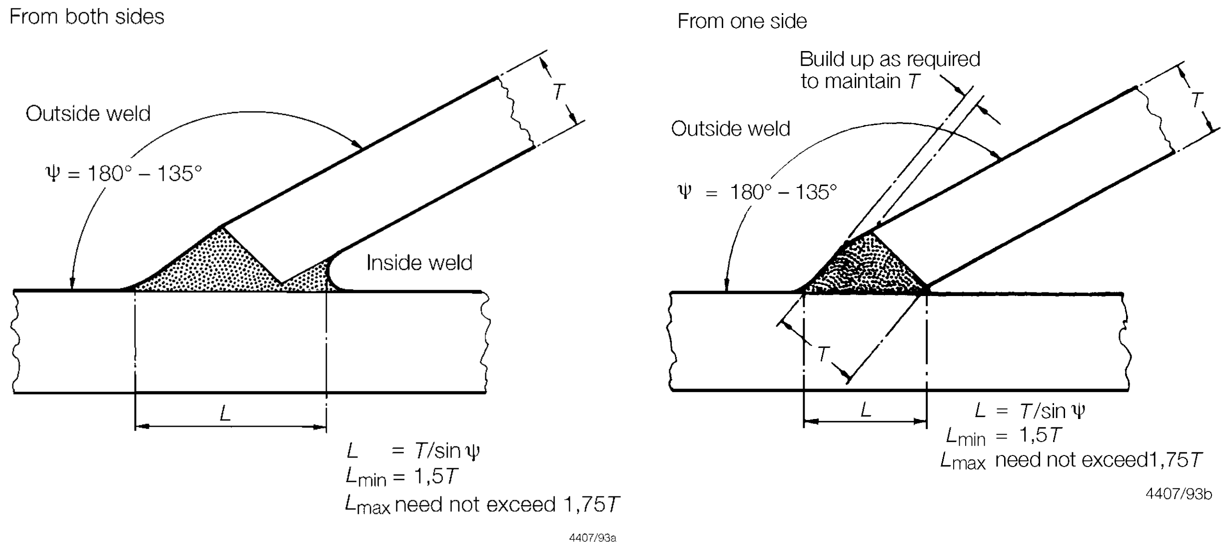


Fig. 8.2.3 Welding at location 1

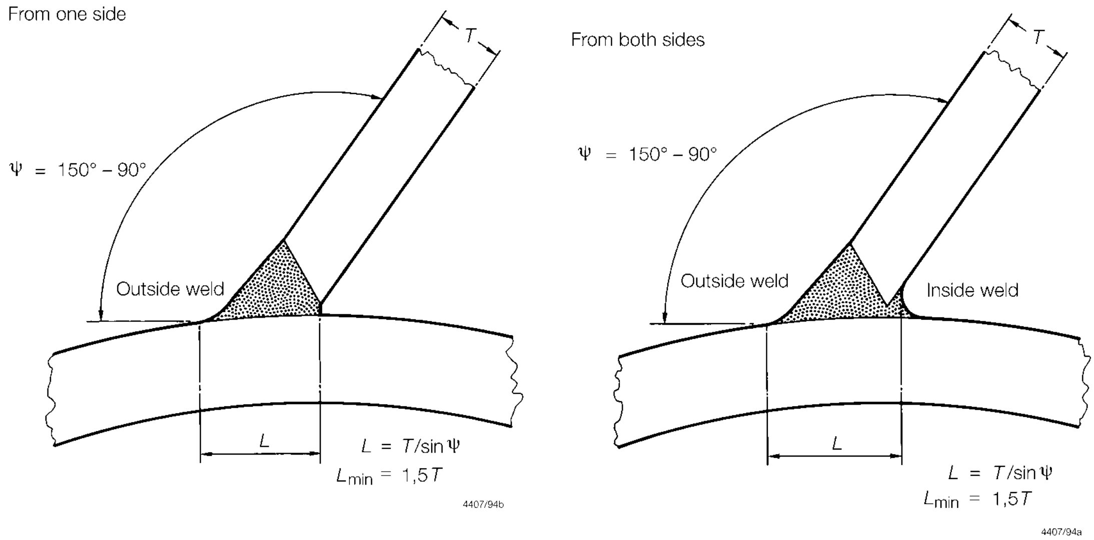


Fig. 8.2.4 Welding at location 2

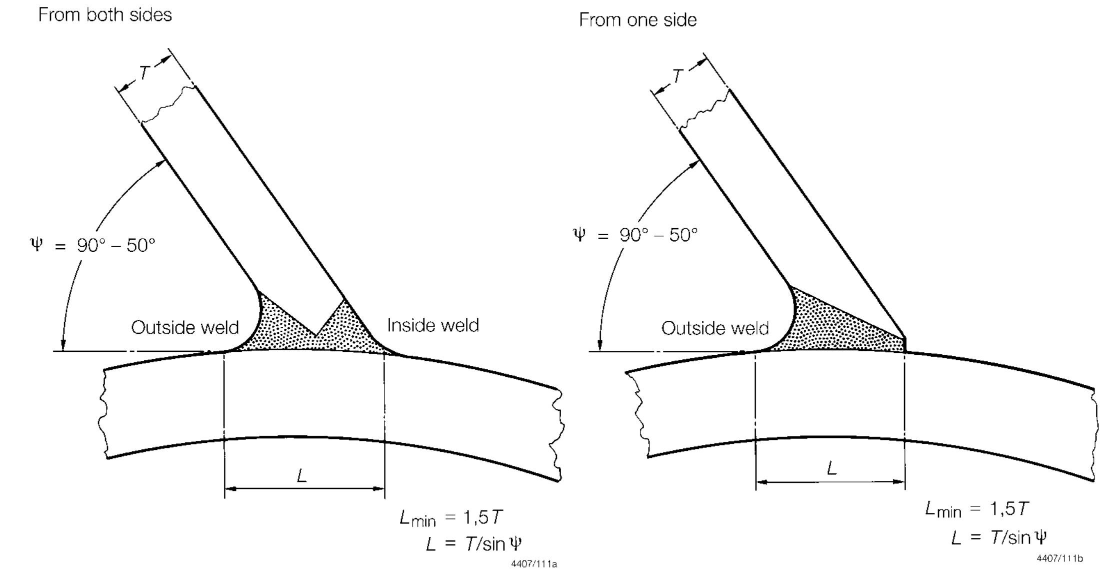


Fig. 8.2.5 Welding at location 3

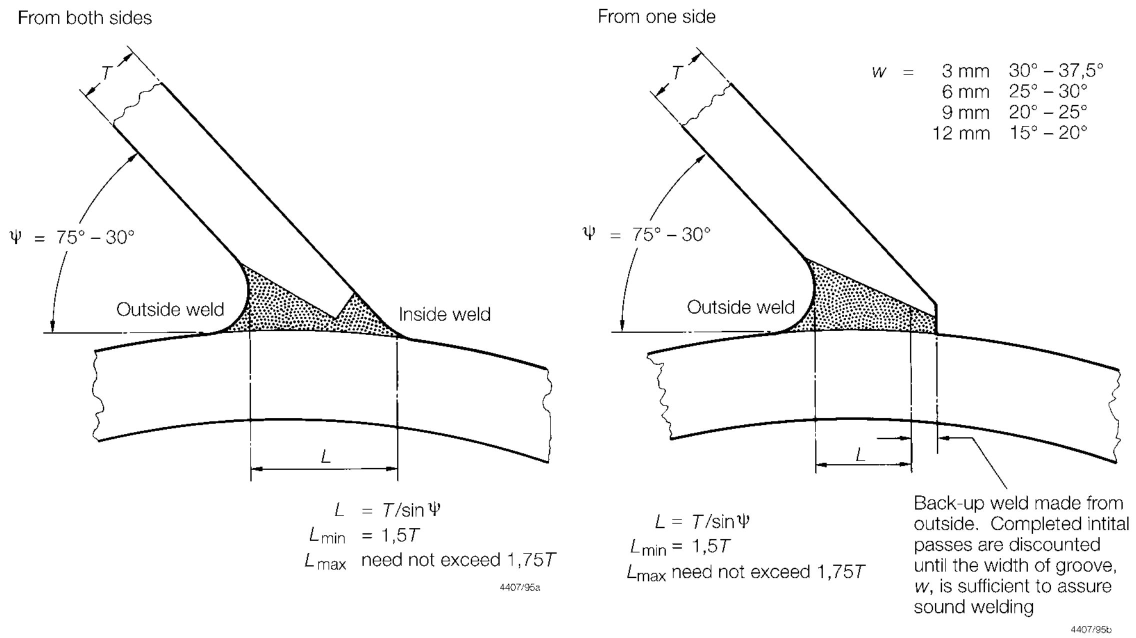


Fig. 8.2.6 Welding at location 4

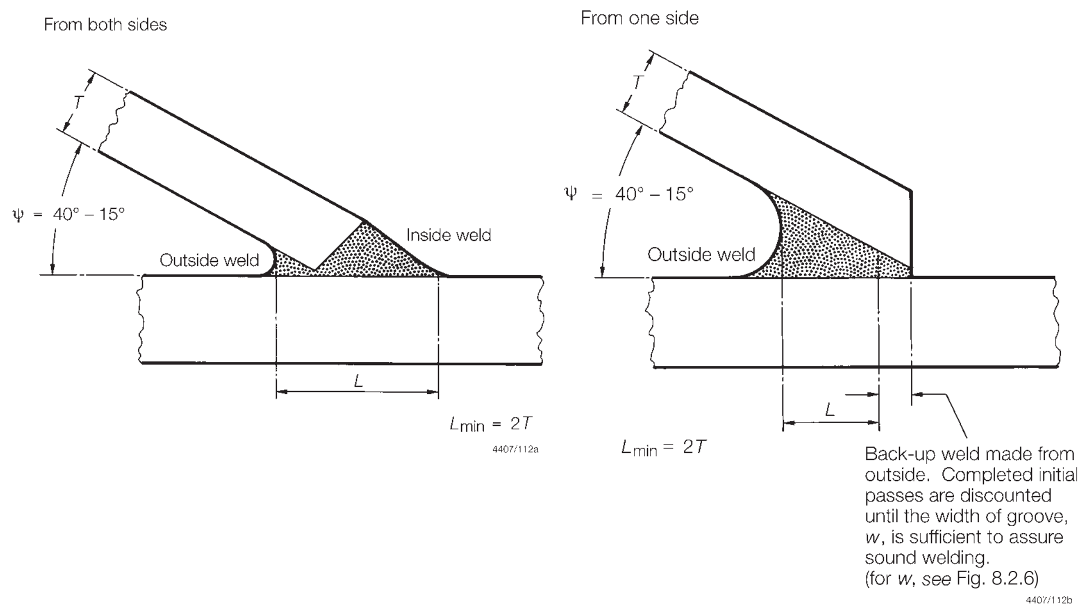


Fig. 8.2.7 Welding at location 5

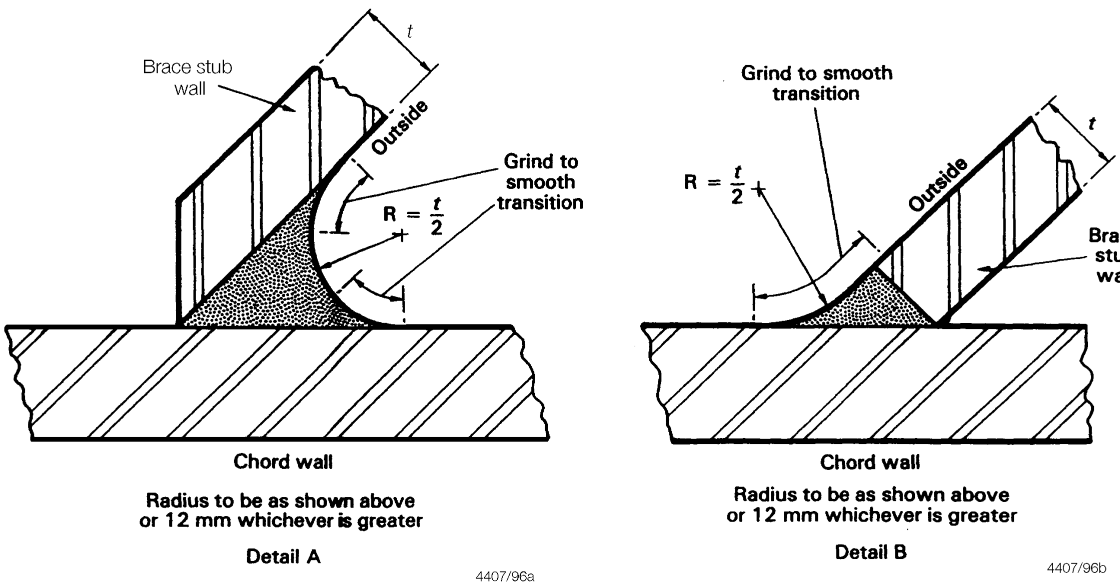


Fig. 8.2.8 Weld grinding

Section 3
Secondary member end connections

3.1 General

3.1.1 For ship units, the design of secondary member end connections is to comply with Part 10. For other unit types, the design of secondary member end connections is to comply with Pt 3, Ch 10,3 of the Rules for Ships.

Section 4
Construction details for primary members

4.1 General

4.1.1 For ship units, the design of construction details for primary members is to comply with Part 10. For other unit types, the design of construction details for primary members is to comply with Pt 3, Ch 10,4 of the Rules for Ships.

4.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

4.2 Geometric properties and proportions

4.2.1 The minimum web thickness of primary shell members in the lower hulls of column-stabilised units is to be not less than $0{,}017S_{\text{w}}$, where S_{w} is spacing of stiffeners on member web, or depth of unstiffened web, in mm.

Section 5
Structural details

5.1 General

5.1.1 For ship units, the design of structural details is to comply with Part 10. For other unit types, the design of structural details is to comply with Pt 3, Ch 10,5 of the Rules for Ships.

5.1.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable.

5.2 Arrangements at intersections of continuous secondary and primary members

5.2.1 In the lower hulls of column-stabilised units, where primary member webs are slotted for the passage of secondary members, web stiffeners are generally to be fitted normal to the face plate of the member to provide adequate support for the loads transmitted. The ends of web stiffeners are to be attached to the secondary members.

5.2.2 Web stiffeners may be flat bars of thickness, t_{w}, with a minimum depth of $0{,}08d_{\text{w}}$ or 75 mm, whichever is the greater. Alternative sections of equivalent moment of inertia may be adopted. The direct stress in the web stiffeners is to be determined in accordance with the Rules for Ships.

5.2.3 For units other than ship units and other surface type units, direct stress in the vertical web stiffener and the shear stresses in the lug, collar plate and weld connections are to satisfy the factors of safety given in Ch 5,2.1.1(a).

5.2.4 For units other than ship units and other surface type units, the head h_1 used to calculate load transmitted to connections of secondary members is to be obtained from the following, as applicable:
(a) h_{o} from Table 6.3.1 in Chapter 6.
(b) h_{T} from Table 6.3.4 in Chapter 6.
(c) h_4 from Table 6.7.1 in Chapter 6.

5.3 Openings

5.3.1 Penetrations in main bracing members are to be avoided as far as possible. Details of essential penetrations or openings in main bracing members are to be submitted for consideration.

5.4 Other fittings and attachments

5.4.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised and the material grade and quality of the bar are to be to the same standard as the deck plate to which it is attached.

5.4.2 Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking into account the intended structural arrangement and attachment details. In general, the material grade and the quality of the attachment are to be to the same standard as the gunwale plates.

5.4.3 Fittings and attachments to main bracing members are to be avoided as far as possible. Where they are necessary, full details are to be submitted for consideration.

Section 6
Fabrication tolerances

6.1 General

6.1.1 All fabrication tolerances are to be in accordance with good shipbuilding practice and be agreed with LR before fabrication is commenced. Where appropriate, tolerances are to comply with a National Standard. In general, the tolerances for the fabrication of structural members for fatigue sensitive areas are to comply with the requirements of this Section.

6.1.2 For cylindrical members, the out of roundness is not to exceed 0,5 per cent of the true mean radius or 25 mm of the true mean internal diameter, whichever is the lesser.

6.1.3 When measuring cylindrical members, the out of roundness is to be measured always as a deviation from the true mean radius in order to avoid errors.

6.1.4 Cylindrical members are not to deviate from straightness by 3 mm or l mm, whichever is the greater, where l is the length of the member, in metres.

6.1.5 The misalignment of plate edges in butt welds is not to exceed the lesser of the following values:

- Special structure 0,1t or 3 mm
- Primary structure 0,15t or 3 mm
- Secondary structure 0,2t or 4 mm

where
t = thickness of the thinnest plate, in mm.

6.1.6 Misalignment of non-continuous plates such as cruciform joints is not to exceed the lesser of the following values:

- Special structure 0,2t or 4 mm
- Primary structure 0,3t or 4 mm
- Secondary structure 0,5t or 5 mm

where
t = thickness of the thinnest plate, in mm.

6.1.7 Plate deformation measured at the mid point between stiffeners or support points is not to exceed the lesser of the following values:

- Special structure $\frac{s}{200}$ mm
- Primary structure $\frac{s}{130}$ or t mm
- Secondary structure $\frac{s}{80}$ or t mm

where
s = stiffener spacing or unsupported panel width, in mm
t = plate thickness, in mm.

Section

Section 1
Anchoring equipment

1.1 General

1.1.1 For self-propelled units to be assigned the figure **(1)** in the character of Classification, the anchoring equipment, i.e., anchors, cables, windlass and winches, etc., necessary for the unit during ocean voyages or location moves, is to be as required by this Section. The Regulations governing the assignment of the figure **(1)** for equipment are given in Pt 1, Ch 2,2.

1.1.2 When the equipment fitted to the unit is designed primarily as positional mooring equipment, consideration will be given to accepting the proposed equipment as equivalent to the Rule requirements but only if the arrangements are such that it can be efficiently used as anchoring equipment. *See also* Pt 1, Ch 2,2.3.3 and Pt 3, Ch 10.

1.1.3 Where the Classification Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the unit, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,2.2.2.

1.2 Equipment number

1.2.1 The requirement for anchors, cables, wires and ropes is to be based on an Equipment Number calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + 2{,}0A_1 + \frac{A_2}{10}$$

where

Δ = moulded displacement in transit condition, in tonnes

A_1 = projected area perpendicular to wind direction when at anchor, in m^2

A_2 = projected area parallel to wind direction when at anchor, in m^2

In calculating the areas A_1 and A_2:

- Masking effect can be taken into account for columns;
- Open trusswork of derricks, booms and towers, etc., may be approximated by taking 30 per cent of the block area of each side, i.e., 60 per cent of the projected area of one side for double sided trusswork.
- When calculating projected areas, account is to be taken of topside process facilities. Special consideration will be given to structure extending outside of the Rule length, *L*.

1.3 Determination of equipment

1.3.1 The basic equipment of anchors and cables is to be determined from Table 9.1.1 and associated notes. Table 9.1.1 is based on the following assumptions:

(a) The anchors will be high holding power anchors of an approved design, *see* 1.5.

(b) The chain cable will be in accordance with the requirements of 1.6.

1.3.2 Where the equipment is based on 1.1.2, the sizes of individual anchors are not to exceed the values given in Table 9.1.1 by more than seven per cent unless the cable sizes are increased as appropriate.

1.3.3 Where the equipment is based on 1.1.2, the minimum cable strength is to be maintained and 1.7.6 is also to be complied with.

1.4 Anchors

1.4.1 Two anchors are to be fitted and arranged so that they may be readily dropped should an emergency occur.

1.4.2 The mass of each anchor is to be as given in Table 9.1.1 except that one anchor may weigh seven per cent less than the Table weight so long as the total weight of the two anchors attached to the cables is not less than twice the tabular weight for one anchor.

1.4.3 Anchors are to be of approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is a considerable change of section.

1.4.4 Positional mooring anchors of the type which are generally similar to conventional marine anchors but which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not normally be accepted as anchoring equipment in accordance with these Rules.

1.4.5 If ordinary ship type stockless bower anchors, not approved as high holding power anchors, are to be used as Rule equipment, the mass of each anchor is to be not less than 1,33 times that listed in Table 9.1.1 for the unit's Equipment Number.

1.4.6 The requirements for manufacture, proof testing and identification of anchors are to be in accordance with Chapter 10 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

Table 9.1.1 Equipment – Anchors and chain cables

Equipment number		Equipment Letter	High holding power anchor mass, in kg	Stud link chain cable			
				Length per anchor, in metres	Diameter, in mm		
Exceeding	Not exceeding				Grade U1	Grade U2	Grade U3
50	70	A	140	110	14	12,5	–
70	90	B	180	110	16	14	–
90	110	C	230	110	17,5	16	–
110	130	D	270	110	19	17,5	–
130	150	E	310	137,5	20,5	17,5	–
150	175	F	360	137,5	22	19	–
175	205	G	430	137,5	24	20,5	–
205	240	H	500	137,5	26	22	20,5
240	280	I	590	165	28	24	22
280	320	J	680	165	30	26	24
320	360	K	770	165	32	28	24
360	400	L	860	192,5	34	30	26
400	450	M	970	192,5	36	32	28
450	500	N	1080	192,5	38	34	30
500	550	O	1190	192,5	40	34	30
550	600	P	1300	220	42	36	32
600	660	Q	1440	220	44	38	34
660	720	R	1580	220	46	40	36
720	780	S	1710	220	48	42	36
780	840	T	1850	220	50	44	38
840	910	U	1990	220	52	46	40
910	980	V	2140	247,5	54	48	42
980	1060	W	2290	247,5	56	50	44
1060	1140	X	2470	247,5	58	50	46
1140	1220	Y	2660	247,5	60	52	46
1220	1300	Z	2840	247,5	62	54	48
1300	1390	A†	3040	247,5	64	56	50
1390	1480	B†	3240	275	66	58	50
1480	1570	C†	3440	275	68	60	52
1570	1670	D†	3670	275	70	62	54
1670	1790	E†	3940	275	73	64	56
1790	1930	F†	4210	275	76	66	58
1930	2080	G†	4500	275	78	68	60
2080	2230	H†	4840	302,5	81	70	62
2230	2380	I†	5180	302,5	84	73	64
2380	2530	J†	5510	302,5	87	76	66
2530	2700	K†	5850	302,5	90	78	68
2700	2870	L†	6230	302,5	92	81	70
2870	3040	M†	6530	302,5	95	84	73
3040	3210	N†	6980	330	97	84	76
3210	3400	O†	7430	330	100	87	78
3400	3600	P†	7880	330	102	90	78
3600	3800	Q†	8330	330	105	92	81
3800	4000	R†	8780	330	107	95	84
4000	4200	S†	9250	330	111	97	87
4200	4400	T†	9700	357,5	114	100	87
4400	4600	U†	10 100	357,5	117	102	90
4600	4800	V†	10 600	357,5	120	105	92
4800	5000	W†	11 000	371,5	122	107	95
5000	5200	X†	11 600	371,5	124	111	97
5200	5500	Y†	12 100	371,5	127	111	97
5500	5800	Z†	12 700	371,5	130	114	100
5800	6100	A*	13 400	371,5	132	117	102
6100	6500	B*	14 100	371,5	–	120	107
6500	6900	C*	15 000	385	–	124	111
6900	7400	D*	16 000	385	–	127	114
7400	7900	E*	17 500	385	–	132	117
7900	8400	F*	18 500	385	–	137	122
8400	8900	G*	19 500	385	–	142	127
8900	9400	H*	20 500	385	–	147	132
9400	10000	I*	22 000	385	–	152	132
10 000	10 700	J*	23 500	385	–	157	137
10 700	11 500	K*	25 000	385	–	157	142
11 500	12 400	L*	26 500	385	–	162	147
12 400	13 400	M*	29 000	385	–	–	152
13 400	14 600	N*	31 500	385	–	–	157
14 600	16 000	O*	34 500	385	–	–	162

NOTES
1. Consideration will be given to the acceptance of equipment differing from these requirements on units which are classed for restricted service (generally those with geographical limitations ensuring service in sheltered or shallow waters only).
2. Special consideration will be given to units which are unmanned during towed voyages and transfer moves.

1.5 High holding power anchors

1.5.1 Anchors of designs for which approval is sought as high holding power anchors are to be tested at sea to show that they have holding powers of at least twice those of approved standard stockless anchors of the same mass.

1.5.2 If approval is sought for a range of sizes, then at least two sizes are to be tested. The smaller of the two anchors is to have a mass not less than one tenth of that of the larger anchor, and the larger of the two anchors tested is to have a mass not less than one tenth of that of the largest anchor for which approval is sought.

1.5.3 The tests are to be conducted on not less than three different types of bottom, which should normally be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

1.5.4 The test should normally be carried out from a tug, and the pull measured by dynamometer or derived from recently verified curves of tug rev/min against bollard pull. A scope of 10 is recommended for the anchor cable, which may be wire rope for this test, but in no case should a scope of less than six be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

1.5.5 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by 1.5.1, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. In case of doubt, a demonstration of these abilities may be required.

1.6 Chain cables

1.6.1 The minimum sizes and lengths of chain cables are to be as required by Table 9.1.1.

1.6.2 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Chapter 10 of the Rules for Materials and are to be graded in accordance with Table 9.1.2.

Table 9.1.2 Anchoring equipment chain grades

Grade	Material	Tensile strength	
		N/mm^2	kgf/mm^2
U1	Mild steel	300–490	(31–50)
U2(a)	Special quality steel (wrought)	490–690	(50–70)
U2(b)	Special quality steel (cast)	490–690	(50–70)
U3	Extra special quality steel	690 min.	(70 min.)

1.6.3 Grade U1 material having a tensile stress of less than 400 N/mm^2 (41 kgf/cm^2) is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

1.6.4 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

1.6.5 As an alternative to the chains listed in Table 9.1.1, consideration will be given to the use of the following:
- Chain cables of Grades R3, R3S and R4 in accordance with Ch 10,3 of the Rules for Materials.
- Wire rope meeting the requirements of the Rules for Materials.

In this case, the length and breaking strength of the wire rope will be specially considered.

1.7 Arrangements for working and stowing anchors and cables

1.7.1 A windlass or winch of sufficient power and suitable for the type of cable is to be provided for each of the anchor cables. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass or winch power.

1.7.2 The windlasses or winches are to be securely fitted and efficiently bedded to suitable positions on the unit. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

1.7.3 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:
$36{,}79d_c^2$ N ($3{,}75d_c^2$ kgf) – for Grade U1 chain,
$41{,}68d_c^2$ N ($4{,}25d_c^2$ kgf) – for Grade U2 chain,
$46{,}6d_c^2$ N ($4{,}75dd_c^2$ kgf) – for Grade U3 chain,
where d_c is the chain diameter, in mm.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:
(i) short-term pull:
1,5 times the continuous duty pull as defined in 1.7.3(a).
(ii) anchor breakout pull:

$$16{,}24W_a + \frac{14{,}0 l_c d_c^2}{100} \text{ N}$$

$$\left(1{,}65W_a + \frac{14{,}2 l_c d_c^2}{1000} \text{ kgf}\right)$$

where
l_c is length of chain cable per anchor, in metres, as given by Table 9.1.1
W_a is the mass of high holding power anchor, in kg, as given in Table 9.1.1

(c) The windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:
$K_b d_c^2$ $(44 – 0,08d_c)$ N
($K_b d_c^2$ $(44 – 0,08d_c)$ kgf)
where
K_b is given in Table 9.1.3.

NOTE
The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's *Type Approval Scheme* will not require shop testing on an individual basis.

Table 9.1.3 Windlass braking factors

Cable grade	K_b	
	Windlass used in conjunction with chain stopper	Chain stopper not fitted
U1	4,41 (0,45)	7,85 (0,8)
U2	6,18 (0,63)	11,0 (1,12)
U3	8,83 (0,9)	15,7 (1,6)

1.7.4 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 1.7.3 are to be submitted, together with detailed plans and an arrangement plan showing the following components:
- Shafting.
- Gearing.
- Brakes.
- Clutches.

1.7.5 During trials on board the unit, the windlass should be shown to be capable of raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of not less than 9 m/min. Where the depth of water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

1.7.6 The cable is to be capable of being paid out in the event of a power failure.

1.7.7 Windlass performance characteristics specified in 1.7.3 and 1.7.5 are based on the following assumptions:
- One cable lifter only is connected to the drive shaft.
- Continuous duty and short-term pulls are measured at the cable lifter.
- Brake tests are carried out with the brakes fully applied and the cable lifter declutched.
- The probability of declutching a cable lifter from the motor with its brake in the off position is minimised.
- Hawse pipe efficiency assumed to be 70 per cent.

1.7.8 An easy lead of the cables from the windlass or winch to the anchors and chain lockers or wire storage drum is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

1.7.9 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. If more than one chain is to be stowed in one locker then the individual cables are to be separated by substantial divisions in the locker.

1.7.10 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63,7 kN (6,5 tonne-f) or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped in an emergency from an accessible position outside the chain locker.

1.7.11 Where wire rope cables are used, these are to be stored on suitable drums. The lead to the drums is to be such that the cables will reel onto the drums reasonably evenly. If the drums are designed to apply the full winch hauling load to the cables then the arrangements, using spooling gear or otherwise, are to ensure even reeling of the cables onto the drums.

1.7.12 Fairleads, hawse pipes, anchor racks and associated structure and components are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The plating and framing in way of these components are to be reinforced as necessary. Columns, lower hulls, footings and other areas likely to be damaged by anchors, chain cables and wire ropes, etc., are to be suitably strengthened.

1.7.13 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:
- a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe;
- access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe if the sea is liable to break over the windlass; and
- for column-stabilised units, *see* Ch 7,4.7.2.

1.7.14 All anchors are to be stowed to prevent moving during transit.

1.8 Testing of equipment

1.8.1 All anchors and chain cables are to be tested at establishments and on machines recognised by LR and under the supervision of LR's Surveyors or other Officers recognised by LR, and in accordance with the Rules for Materials.

1.8.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the unit.

1.8.3 Steel wire ropes are to be tested as required by the Rules for Materials.

■ *Section 2* Towing arrangements

2.1 General

2.1.1 All non-self-propelled units which are to be wet-towed to their operating location are to be fitted with adequate arrangements for towing.

2.1.2 Plans and full particulars of the unit's towing facilities are to be submitted for approval, together with calculations or model test data supporting the assigned system design load. The maximum permitted static bollard pull for each towing arrangement is to be stated on the plans.

2.1.3 Oil storage units which may be towed in order to avoid hazards or extreme environmental conditions may require emergency towing arrangements in accordance with IMO Resolution MSC 35(63) for oil tankers when required by a National Administration. Where emergency towing arrangements are required, plans of the system and structural arrangements are to be submitted for approval. *See also* Pt 3, Ch 13,9 of the *Rules and Regulations for the Classification of Ships*.

2.2 Towing system

2.2.1 Units are to be provided with a main towing system suitable for towing with one or two towing vessels and in addition it is recommended that an emergency towing system is provided.

2.2.2 The emergency towing system may be arranged by using the unit's anchor line or similar system.

2.2.3 The main towing system is to be suitable for the design load in accordance with 2.1.2 but is not to be taken less than 75 tonne-f.

2.2.4 The components of the towing system are to be manufactured and tested in accordance with Chapter 10 of the Rules for Materials.

2.2.5 The main towing system is to consist of not less than the following parts:

- Two attachments to the unit (e.g. towing brackets).
- Two chain/wire rope pendants connected to the unit.
- One triangular plate or equivalent.
- Two wire rope towlines as 'weak links'.
- Shackles for connections.

2.2.6 Wire ropes are to have 'hard eyes' fitted at their ends.

2.2.7 Where towing bridles can be subjected to heavy wear due to chafing, chains are to be used.

2.2.8 The attachments to the unit are to be as far apart as practicable and on column-stabilised units the attachments are to be fitted to the lower hulls.

2.2.9 The length of the towing pendants attached to the unit is not to be less than the distance between the attachments.

2.2.10 The position and arrangement of the towing attachments are to be such that it is possible to change the chain/wire towing pendant connections quickly in calm water.

2.2.11 When towing with two towing vessels, each towline (weak link) is to be fitted between the unit's towing pendants and the towlines of the towing vessels. When towing with one towing vessel, the towline (weak link) is to be connected between the triangular plate or equivalent and the towline of the towing vessel.

2.2.12 The length of each towline (weak link) is, in general, not to be less than 50 m so that the connection to the towline of the towing vessel is at a safe distance from the unit.

2.3 Strength

2.3.1 Each towing pendant connected to the unit is to have a minimum breaking strength of three times the design load, *see* 2.2.3.

2.3.2 The towline (weak link) is to have a breaking strength of approximately 85 per cent of the breaking strength of the towing pendant connected to the unit.

2.3.3 The towing pendant connections to the unit, triangular plate and shackles are to have a breaking strength greater than the strongest part of the towing system.

2.3.4 The attachments to the unit are to be designed for a towing direction of 0° to 90° off centreline port and starboard. Account is to be taken of the specified range of inclination angles.

2.3.5 Towing brackets or pad-eyes and their support structure are to be designed to the breaking strength of the attached towing pendant. The permissible stresses are to be in accordance with Ch 5,2.1.1(c).

2.4 Retrieval system

2.4.1 Means are to be provided to retrieve the unit's towing pendants or bridle in the event that the towing vessel's towline or the towline (weak link) should break.

2.5 Spare parts

2.5.1 It is recommended that an adequate number of spare parts for the towing system be provided on board during towing operations.

Section 1
General

1.1 Application

1.1.1 This Chapter applies to all the unit types detailed in Part 3, and requirements are given for rudders, nozzles, steering gear, tunnel thrust unit structure and stabiliser structure.

1.1.2 Where units are fitted with conventional rudders, the scantlings and arrangements are to comply with the requirements of this Chapter.

1.1.3 Where a self-propelled unit is fitted with a non-conventional rudder or the rudder is omitted, special consideration will be given to the steering system so as to ensure that an acceptable degree of reliability and effectiveness is provided in order to achieve equivalence to the normal Rule requirements.

1.2 General symbols

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

L, B, C_b as defined in Ch 1,5.1

σ_0 = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 (kgf/mm^2)

k = higher tensile steel factor, *see* Ch 2,1.2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is included in the class of a unit, additional requirements are applicable as detailed in Pt 3, Ch 6.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

Section 2
Rudders

2.1 General

2.1.1 Requirements for rudders are given in Pt 3, Ch 13,2 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with.

2.1.2 Where an **OIWS** (In-water Survey) notation is to be assigned, *see also* Pt 1, Ch 2,2.4.9, means are to be provided for ascertaining the rudder pintles and bush clearances and for verifying the security of the pintles in their sockets with the unit afloat.

2.1.3 When a ship unit is to be converted and classed as a floating offshore installation and the rudder is inoperative, it is strongly recommended that the rudder be removed to prevent damage to the steering gear in storm conditions.

2.1.4 If the rudder is removed in accordance with 2.1.3, the hull aperture is to be fitted with a suitable blanking plate and sealing arrangements to ensure watertight integrity of the hull. The scantlings and arrangements are to comply with Chapter 7.

2.1.5 Where rudders are left in situ on ship units *see* Part 5, Chapter 19, Section 1.1.3.

2.1.6 The machinery and equipment is to be subject to survey in accordance with the requirements of Pt 1, Ch 3.

Section 3
Fixed and steering nozzles

3.1 General

3.1.1 Requirements for fixed and steering nozzles are given in Pt 3, Ch 13,3 of the Rules for Ships, which should be complied with.

Section 4
Steering gear and allied systems

4.1 General

4.1.1 Requirements for steering gear are given in Pt 5, Ch 19.

4.1.2 When units are fitted with steering arrangements consisting of Azimuth thrusters, *see* Pt 5, Ch 20.

Section 5
Tunnel thrust unit structure

5.1 General

5.1.1 Requirements for tunnel thrust unit structure are given in Pt 3, Ch 13,5 of the Rules for Ships, which should be complied with.

5.1.2 Thrust units are to be enclosed in suitable watertight spaces to prevent flooding in the case of leakage or damage to the thrust unit.

Section 6
Stabiliser structure

6.1 General

6.1.1 Requirements for stabiliser structure are given in Pt 3, Ch 13,6 of the Rules for Ships, which should be complied with.

■ *Section 1* General

1.1 Definitions

1.1.1 **Quality Assurance Scheme**. LR's Quality Assurance requirements for the hull construction of mobile offshore units are defined as follows:

(a) **Quality Assurance**. All activities and functions concerned with the attainment of quality including documentary evidence to confirm that such attainment is met.
(b) **Quality system**. The organisation structure, responsibilities, activities, resources and events laid down by Management that together provide organised procedures (from which data and other records are generated) and methods of implementation to ensure the capability of the fabrication yard to meet quality requirements.
(c) **Quality programme**. A documented set of activities, resources and events serving to implement the quality system of an organisation.
(d) **Quality plan**. A document derived from the quality programme setting out the specific quality practices, special processes, resources and activities relevant to a particular unit or series of similar units. This document will also indicate the stages at which, as a minimum, direct survey and/or system monitoring will be carried out by the Classification Surveyor.
(e) **Quality control**. The operational techniques and activities used to measure and regulate the quality of construction to the required level.
(f) **Inspection**. The process of measuring, examining, testing, gauging or otherwise comparing the item with the approved drawings and the fabrication yard's written standards, including those which have been agreed by LR for the purposes of classification of the specific type of unit concerned.
(g) **Assessment**. The initial comprehensive review of the fabrication yard's quality systems, prior to the granting of approval, to establish that all the requirements of these Rules have been met.
(h) **Audit**. A documented activity aimed at verifying by examination and evaluation that the applicable elements of the quality programme continue to be effectively implemented.
(j) **Hold point**. A defined stage of manufacture beyond which the work must not proceed until the inspection has been carried out by all the relevant personnel.
(k) **System monitoring**. The act of checking, on a regular basis, the applicable processes, activities and associated documentation that the Fabricator's quality system continues to operate as defined in the quality programme.
(l) **Special process**. A process where some aspects of the required quality cannot be assured by subsequent inspection of the processed material alone. Manufacturing special processes include welding, forming and the application of protective treatments. Inspection and testing processes classified as special processes include non-destructive examination and pressure and leak testing.

1.2 Scope of the Quality Assurance Scheme

1.2.1 This Chapter specifies the minimum Quality system requirements for a fabrication yard to construct offshore units under LR's *Quality Assurance Scheme*.

1.2.2 For the purposes of this Chapter of the Rules, 'construction (hull)' comprises the primary bracings, columns, legs, footings, hull structure, appendages, superstructure, deckhouses and closing appliances, all as required by the Rules.

1.2.3 Although the requirements of this scheme are, in general, for steel structures of all welded construction, other materials for use in hull construction will be considered.

■ *Section 2* Application

2.1 Certification of the fabrication yard

2.1.1 Requirements for application are given in Pt 3, Ch 15,2 of the Rules for Ships, which should be complied with.

Section 3
Particulars to be submitted

3.1 Documentation and procedures

3.1.1 Requirements for particulars to be submitted are given in Pt 3, Ch 15,3 of the Rules for Ships, which should be complied with.

Section 4
Requirements of Parts 1 and 2 of the Scheme

4.1 General

4.1.1 Requirements for Parts 1 and 2 of the scheme are given in Pt 3, Ch 15,4 of the Rules for Ships, which should be complied with.

Section 5
Additional requirements for Part 2 of the Scheme

5.1 Quality System procedures

5.1.1 Additional requirements for Part 2 of the scheme are given in Pt 3, Ch 15,5 of the Rules for Ships, which should be complied with.

Section 6
Initial assessment of fabrication yard

6.1 General

6.1.1 Requirements for the initial assessment of the Shipyard are given in Pt 3, Ch 15,6 of the Rules for Ships, which should be complied with.

Section 7
Approval of the fabrication yard

7.1 General

7.1.1 Requirements for approval of the shipyard are given in Pt 3, Ch 15,7 of the Rules for Ships, which should be complied with.

Section 8
Maintenance of approval

8.1 General

8.1.1 Requirements for maintenance of approval are given in Pt 3, Ch 15,8 of the Rules for Ships, which should be complied with.

Section 9
Suspension or withdrawal of approval

9.1 General

9.1.1 Requirements for suspension or withdrawal of approval are given in Pt 3, Ch 15,9 of the Rules for Ships, which should be complied with.

Fatigue – S-N Curves, Joint Classification and Stress Concentration Factors

Section

■ *Section A1* General

A1.1 Application

A1.1.1 This Appendix contains details of acceptable design S-N curves and joint classification. The details contained in this Appendix take due account of the fatigue data published in the *UK HSE Guidance Notes for Design, Construction and Classification of Offshore Installations,* 4th edition, 1990.

A1.1.2 All tubular joints are assigned Class T. Other types of joints are assigned Class B, C, D, E, F, F2, G or W depending upon:

- geometric arrangements;
- direction of applied stress; and
- method of fabrication and inspection.

A1.1.3 Details of the design S-N curves are given in Section A2, joint classifications are given in Section A3.

A1.1.4 Guidance on the determination of global stress concentration factors is given in Section A4.

A1.1.5 Other methods may be used after special consideration and agreement with LR. Detailed proposals are to be submitted.

■ *Section A2* Fatigue design S-N curves

A2.1 Basic design S-N curves

A2.1.1 The basic design curves consist of linear relationships between $\log(S_B)$ and log(N). They are based upon a statistical analysis of appropriate experimental data and may be taken to represent two standard deviations below the mean line. Thus the basic S-N curves are of the form:

$$\log(N) = \log(K_1) - d\sigma - m\log(S_B)$$

where

N = the predicted number of cycles to failure under stress range S_B
K_1 = a constant relating to the mean S-N curve
d = the number of standard deviations below the mean
σ = the standard deviation of log N
m = the inverse slope of the S-N curve.

The relevant values of these terms are shown in Table A2.1. Table A2.1 also shows the value of K_2
where

$$\log(K_2) = \log(K_1) - 2\sigma$$

which is relevant to the basic design curves (i.e. for d = 2).

A2.2 Modifications to basic S-N curves

A2.2.1 The factors listed in this sub-Section are to be considered when using the basic S-N curve.

A2.2.2 **Unprotected joints in sea-water**. For joints without adequate corrosion protection which are exposed to sea water the basic S-N curve is reduced by a factor of two on life for all joint classes.

NOTE
For high strength steels, i.e. σ_y >400 N/mm^2, a penalty factor of two may not be adequate. In addition the correction relating to the numbers of small stress cycles is not applicable.

A2.2.3 **Effect of plate thickness**. The fatigue strength of welded joints is to some extent dependent on plate thickness, strength decreasing with increasing thickness. The basic S-N curves shown in Figs. A2.2 and A2.3 relate to thicknesses as follows:

- Nodal joints (Class T) up to 32 mm
- Non-nodal joints (Classes B-G) up to 22 mm.

For joints of other thicknesses, correction factors on life or stress have to be applied to produce a relevant S-N curve. The correction on stress range is of the form:

$$S = S_B\left(\frac{t_B}{t}\right)^{1/4}$$

where

S = the fatigue strength of the joint under consideration
S_B = the fatigue strength of the joint using the basic S-N curve
t = the actual thickness of the member under consideration
t_B = the thickness relevant to the basic S-N curve

Substituting the above relationship in the basic S-N curve equation in A2.1.1 and using the equation for $\log(K_2)$ in A2.1.1 yields the following equation of the S-N for a joint member thickness t:

$$\log(N) = \log K_2 - m\log\left(\frac{S}{\left(\frac{t_B}{t}\right)^{1/4}}\right)$$

A value of t = 22 mm should be used for calculating endurance N when the actual thickness is less than 22 mm.

NOTE
This gives a benefit for nodal joints with wall thicknesses in the range of 22 to 32 mm.

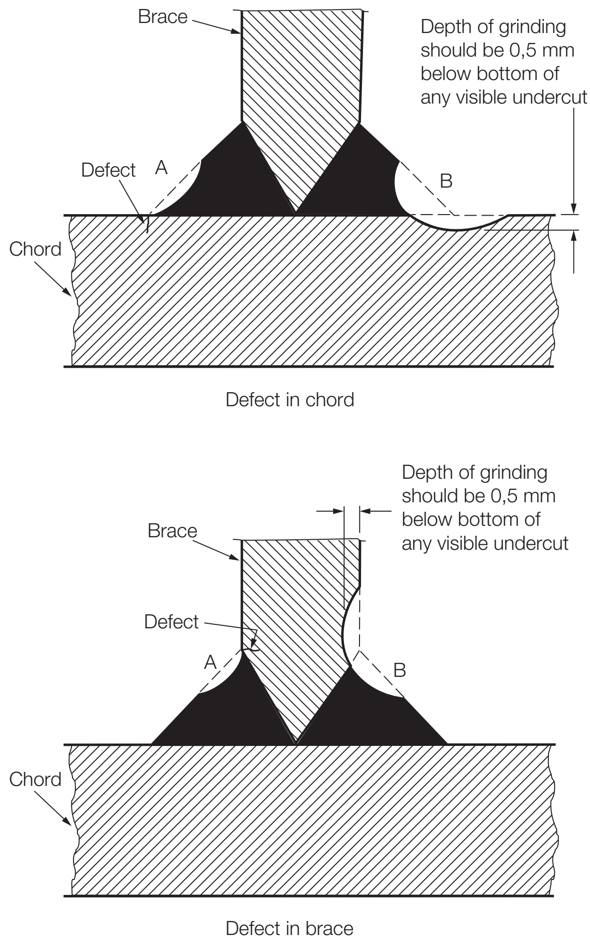
Table A2.1 Details of basic S-N curves

Class	K_1	K_1		m	Standard deviation		K_2	S_o
		$\log_{10}$	$\log_e$		$\log_{10}$	$\log_e$		N/mm^2
B	2,343 x 10^{15}	15,3697	35,3900	4,0	0,1821	0,4194	1,01 x 10^{15}	100
C	1,082 x 10^{14}	14,0342	32,3153	3,5	0,2041	0,4700	4,23 x 10^{13}	78
D	3,988 x 10^{12}	12,6007	29,0144	3,0	0,2095	0,4824	1,52 x 10^{12}	53
E	3,289 x 10^{12}	12,5169	28,8216	3,0	0,2509	0,5777	1,04 x 10^{12}	47
F	1,289 x 10^{12}	12,2370	28,1770	3,0	0,2183	0,5027	0,63 x 10^{12}	40
F2	1,231 x 10^{12}	12,0900	27,8387	3,0	0,2279	0,5248	0,43 x 10^{12}	35
G	0,566 x 10^{12}	11,7525	27,0614	3,0	0,1793	0,4129	0,25 x 10^{12}	29
W	0,368 x 10^{12}	11,5662	26,6324	3,0	0,1846	0,4251	0,16 x 10^{12}	25
T	4,577 x 10^{12}	12,6606	29,1520	3,0	0,2484	0,5720	1,46 x 10^{12}	53, *see* Note 1

NOTES
1. Idealised hot spot stress
2. For example, the T curve expressed in terms of $\log_{10}$ is:
   $\log_{10}(N) = 12,6606 – 0,2484d – 3\log_{10}(S_B)$

A2.2.4 **Weld improvement**. For welded joints involving potential fatigue cracking from the weld toe, an improvement in strength by at least 30 per cent, equivalent to a factor of 2,2 on life, can be obtained by controlled local machining or grinding of the weld toe. This is to be carried out either with a rotary burr or by disc grinding. The treatment should produce a smooth concave profile at the weld toe with the depth of the depression penetrating into the plate surface to at least 0,5 mm below the bottom of any visible undercut, *see* Fig. A2.1, and ensuring that no exposed defects remain. The maximum depth of local machining or grinding is not to exceed 2 mm or five per cent of the plate thickness. In the case of a multi-pass weld more than one weld toe may need to be dressed. Where toe grinding is used to improve the fatigue life of fillet welded connections, care should be taken to ensure that the required throat size is maintained. The benefit of grinding is only applicable for welded joints which are adequately protected from sea-water corrosion. Any credit for other beneficial treatments should be justified. It is recommended that no advantage for toe grinding should be taken at the initial design stage. Overall weld profiling is preferred but no improvement in fatigue strength can be allowed unless accompanied by toe grinding. In the case of partial penetration welds, where failure may occur from the weld root, grinding of the weld toe cannot be relied upon to give an increase in strength.

A2.2.5 Special consideration will be given to alternative techniques intended to improve weld quality. Detailed proposals are to be submitted.



Grinding a weld toe tangentially to the plate surface as at A, will produce little improvement in strength. Grinding must extend below the plate surface, as at B, in order to remove toe defects.

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Fig. A2.1 Weld improvements

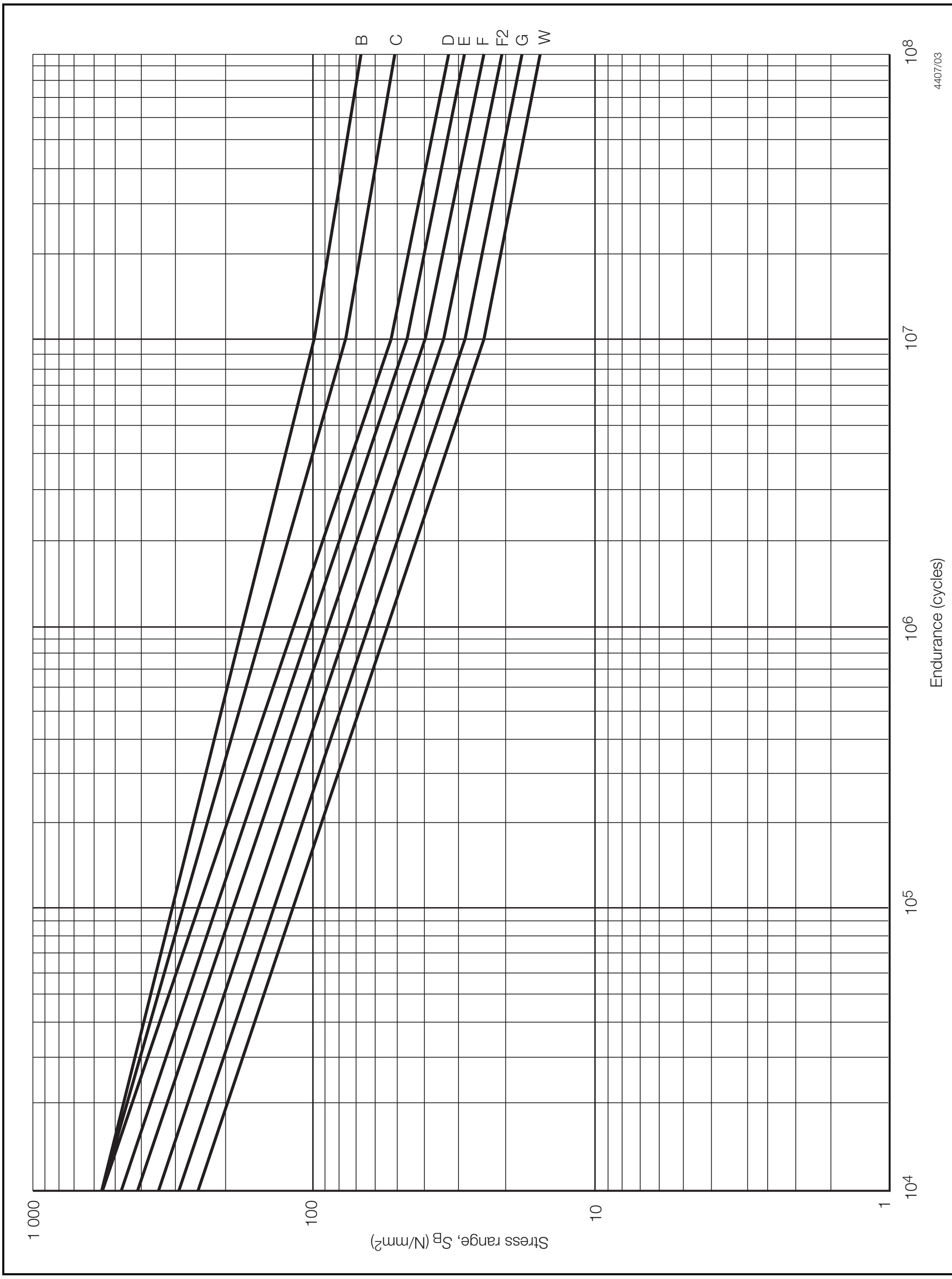


Fig. A2.2 Basic design S-N curve for non-nodal joints

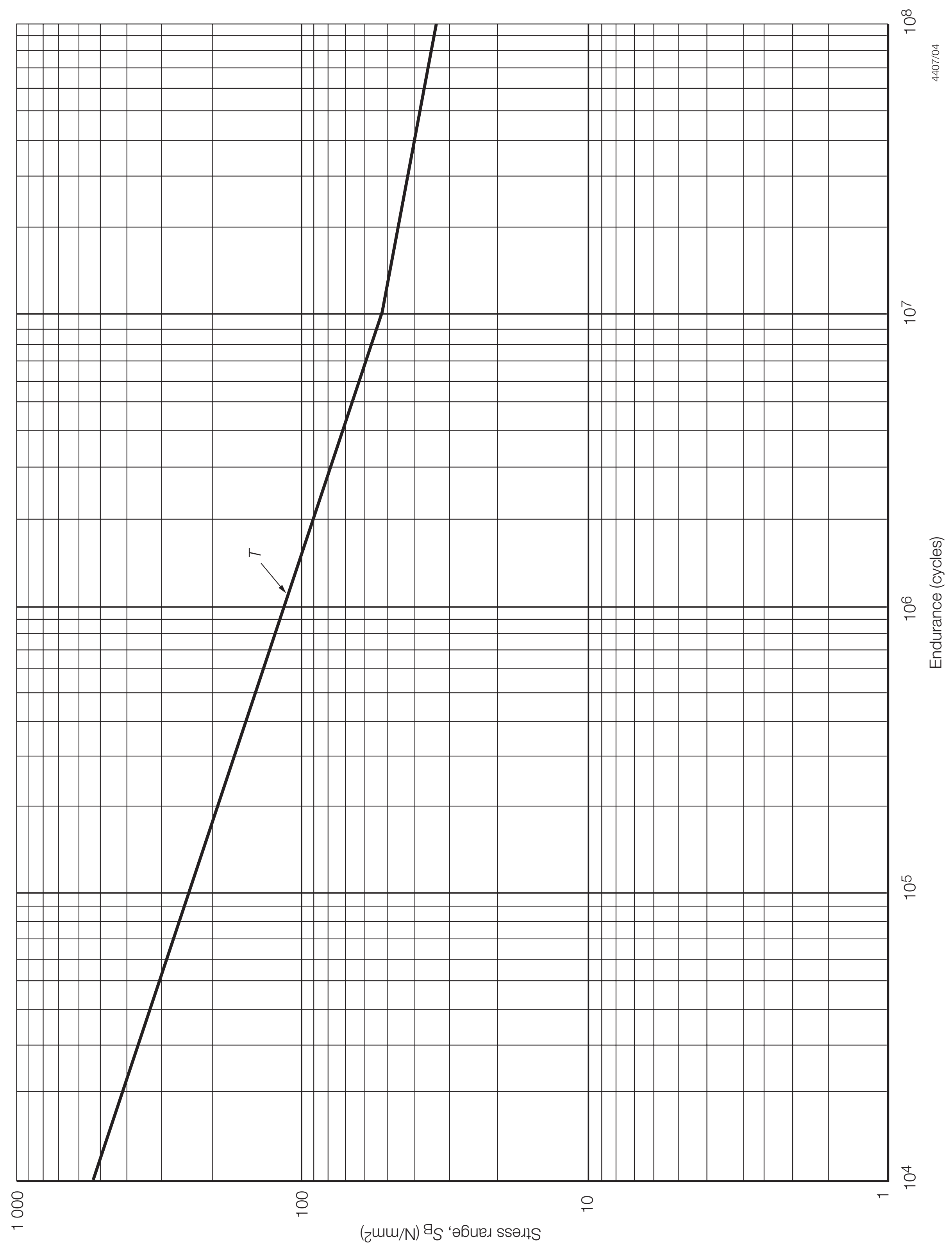


Fig. A2.3 Basic design S-N curves for nodal joints

A2.3 Treatment of low stress cycles

A2.3.1 Under constant amplitude stresses there is a certain stress range, which varies both with the environment and with the size of any initial defects, below which an indefinitely large number of cycles can be sustained. In air and sea-water with adequate protection against corrosion, and with details fabricated in accordance with this Appendix, it is assumed that this non-propagating stress range, S_o. is the stress corresponding to $N = 10^7$ cycles; relevant values of S_o are shown in Table A2.1.

A2.3.2 When the applied fluctuating stress has varying amplitude, so that some of the stress ranges are greater and some less than S_o, the larger stress ranges will cause growth of the defect, thereby reducing the value of the non-propagating stress range below S_o. In time, an increasing number of stress ranges, below S_o can themselves contribute to crack growth. The final result is an earlier fatigue failure than could be predicted by assuming that all stress ranges below S_o are ineffective.

A2.3.3 An adequate estimate of this behaviour can be made by assuming that the S-N curve has a change of inverse slope from m to $m + 2$ at $N = 10^7$ cycles. This correction does not apply in the case of unprotected joints in sea-water.

A2.4 Treatment of high stress cycles

A2.4.1 For high stress cycles the design S-N curve for nodal joints (the T curve) may be extrapolated back linearly to a stress range equal to twice the material yield stress $2\sigma_y$.

A2.4.2 An example of the high stress cycle limit for the T curve is given in Fig. A2.4.

A2.4.3 A similar procedure can be adopted for non-nodal joints (Classes B-G) where local bending or other structural stress concentrating features are involved and the relevant stress range includes the stress concentration.

A2.4.4 If the joint is in a region of simple membrane stress then the design S-N curves may be extrapolated back linearly to a stress range given by twice the tensile stress limitations given in these Rules.

A2.4.5 For the Class W curve, extrapolation may be made back as for the non-nodal joints but to a stress range defined by half the values given above (i.e. with reference to shear instead of tensile stress).

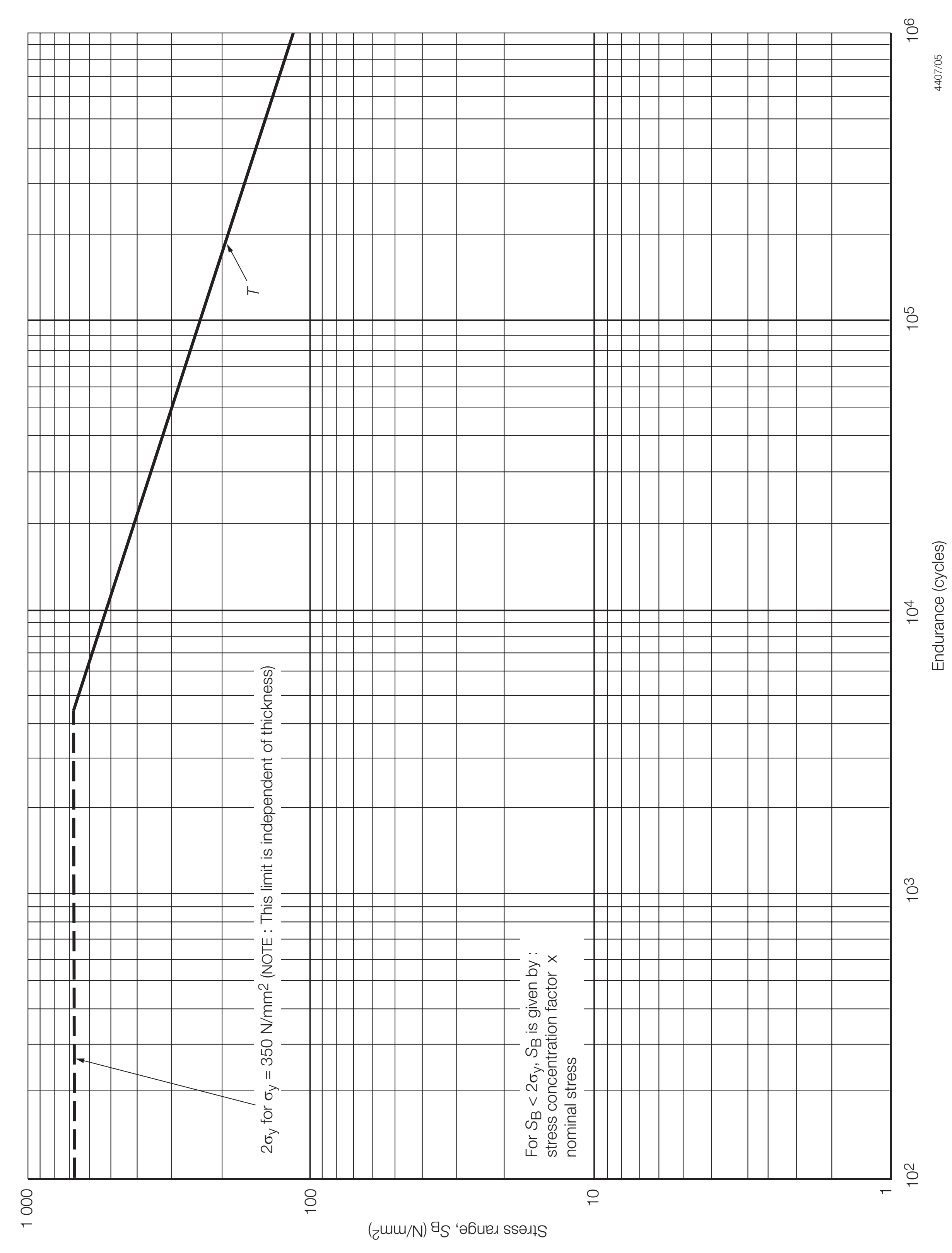


Fig. A2.4 Treatment of high cyclic stresses for the T-curve and a material with yield stress = 350 N/mm^2

■ *Section A3* Fatigue joint classification

A3.1 General

A3.1.1 Fatigue joint classification details including notes on mode of failure and typical examples are given in Table A3.1.

Table A3.1 Fatigue joint classification (*see continuation*)

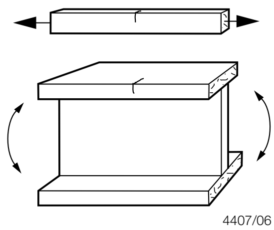
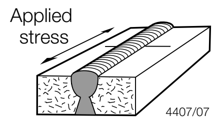
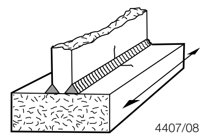
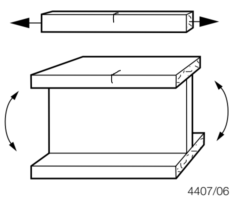
Type number, description and notes on mode of failure	Class explanatory comments	Examples, including failure modes
TYPE 1 MATERIAL FREE FROM WELDING Notes on potential modes of failure: In plain steel, fatigue cracks initiate at the surface, usually either at surface irregularities or at corners of the cross-section. In welded construction, fatigue failure will rarely occur in a region of plain material since the fatigue strength of the welded joints will usually be much lower. In steel with rivet or bolt holes or other stress concentrations arising from the shape of the member, failure will usually initiate at the stress concentration.		
1.1 Plain steel (a) In the as-rolled condition, or with cleaned surfaces but with no flame-cut edges of re-entrant corners.	B Beware of using Class B for a member which may acquire stress concentration during its life, e.g. as a result of rust pitting. In such an event Class C would be more appropriate.	
(b) As (a) but with any flame-cut edges subsequently ground or machined to remove all visible sign of the drag lines.	B Any re-entrant corners in flame-cut edges should have a radius greater than the plate thickness.	
(c) As (a) but with the edges machine flame-cut by a controlled procedure to ensure that the cut surface is free from cracks.	C Note, however, that the presence of a re-entrant corner implies the existence of a stress concentration so that the design stress should be taken as the net stress multiplied by the relevant stress concentration factor.	
TYPE 2 CONTINUOUS WELDS ESSENTIALLY PARALLEL TO THE DIRECTION OF APPLIED STRESS Notes on potential modes of failure: With the excess weld metal dressed flush, fatigue cracks would be expected to initiate at weld defect locations. In the as-welded condition, cracks might initiate at stop-start positions or, if these are not present, at weld surface ripples. General comments: (a) Backing strips: If backing strips are used in making these joints: (i) they must be continuous; and (ii) if they are attached by welding those welds must also comply with the relevant Class requirements (note particularly that tack welds, unless subsequently ground out or covered by a continuous weld, would reduce the joint to Class F, *see* joint 6.5). (b) Edge distance: An edge distance criterion exists to limit the possibility of local stress concentrations occurring at unwelded edges as a result for example, of undercut, weld spatter or accidental overweave in manual fillet welding (*see also* notes on joint Type 4). Although an edge distance can be specified only for the 'width' direction of an element, it is equally important to ensure that no accidental undercutting occurs on the unwelded corners of, for example, cover plates or box girder flanges. If it does occur it should subsequently be ground smooth.		
2.1 Full or partial penetration butt welds, or fillet welds. Parent or weld metal in members, without attachments built up of plates or sections, and joined by continuous welds.		
(a) Full penetration butt welds with the weld overfill dressed flush with the surface and finish-machined in the direction of stress, and with the weld proved free from significant defects by non-destructive examination.	B The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects.	
(b) Butt or fillet welds with the welds made by an automatic submerged or open arc process and with no stop-start positions within the length.	C If an accidental stop-start occurs in a region where Class C is required remedial action should be taken so that the finished weld has a similar surface and root profile to that intended.	
(c) As (b) but with the weld containing stop-start positions within the length.	D For situation at the ends of flange cover plates *see* joint Type 6.4.	

Table A3.1 Fatigue joint classification (*continued*)

<table>
<tr><th colspan="2">Type number, description and notes on mode of failure</th><th></th><th>Class explanatory comments</th><th>Examples, including failure modes</th></tr>
<tr><td colspan="5">TYPE 3 TRANSVERSE BUTT WELDS IN PLATES (i.e. essentially perpendicular to the direction of applied stress)
Notes on potential modes of failure:

With the weld ends machined flush with the plate edges, fatigue cracks in the as-welded condition normally initiate at the weld toe, so that the fatigue strength depends largely upon the shape of the weld overfill. If this is dressed flush the stress concentration caused by it is removed and failure is then associated with weld defects. In welds made on a permanent backing strip, fatigue cracks initiate at the weld metal/strip junction and in partial penetration welds (which should not be used under fatigue conditions), at the weld root.
Welds made entirely from one side, without a permanent backing, require care to be taken in the making of the root bead in order to ensure a satisfactory profile.

Design stresses:
In the design of butt welds of Types 3.1 or 3.2 which are not aligned, the stresses must include the effect of any eccentricity. An approximate method of allowing for eccentricity in the thickness direction is to multiply the normal stress by $\left(1 + 3\,\frac{e}{t}\right)$, where

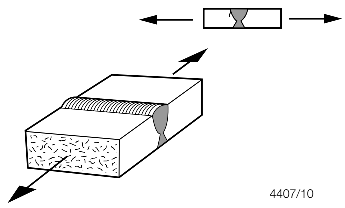
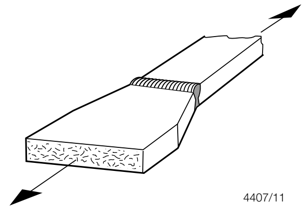
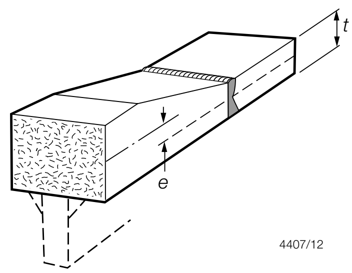
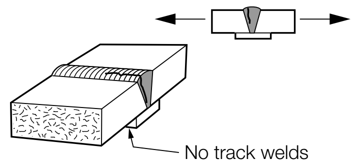
e is the distance between centres of thickness of the two abutting members: if one of the members is tapered, the centre of the untapered thickness must be used; and
t is the thickness of the thinner member.
With connections which are supported laterally, e.g. flanges of a beam which are supported by the web, eccentricity may be neglected.</td></tr>
<tr><td>3.1</td><td>Parent metal adjacent to or weld metal in full penetration butt joints welded from both sides between plates of equal width and thickness or where differences in width and thickness are machined to a smooth transition not steeper than 1 in 4.</td><td></td><td>Note that this includes butt welds which do not completely traverse the member, such as circular welds used for inserting infilling plates into temporary holes.</td><td></td></tr>
<tr><td>(a)</td><td>With the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination.</td><td>C</td><td>The significance of defects should be determine with the aid of specialist advice and/or by the use of fracture mechanic analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects.</td><td></td></tr>
<tr><td>(b)</td><td>With the welds made, either manually or by an automatic process, other than submerged arc, provided all runs are made in the downhand position.</td><td>D</td><td>In general, welds made by the submerged arc process, or in positions other than downhand, tend to have a poor reinforcement shape, from the point of view of fatigue strength. Hence such welds are downgraded from D to E.</td><td></td></tr>
<tr><td>(c)</td><td>Welds made other than in (a) or (b).</td><td>E</td><td>In both (b) and (c) of the corners of the cross-section of the stressed element at the weld toes should be dressed to a smooth profile.
Note that step changes in thickness are in general, not permitted under fatigue conditions, but that where the thickness of the thicker member is not greater than 1,15 x the thickness of the thinner member, the change can be accommodated in the weld profile without any machining. Step changes in width lead to large reductions in strength (see joint Type 3.3).</td><td></td></tr>
<tr><td>3.2</td><td>Parent metal adjacent to, or weld metal in, full penetration butt joints made on a permanent backing strip between plates of equal width and thickness or with differences in width and thickness machined to a smooth transition not steeper than 1 in 4.</td><td>F</td><td>Note that if the backing strip is fillet welded or tack welded to the member the joint could be reduced to Class G (joint Type 4.2).</td><td></td></tr>
</table>

Table A3.1 Fatigue joint classification (*continued*)

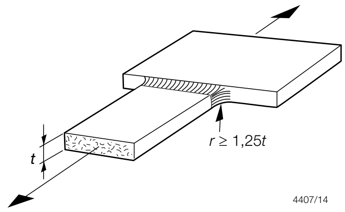
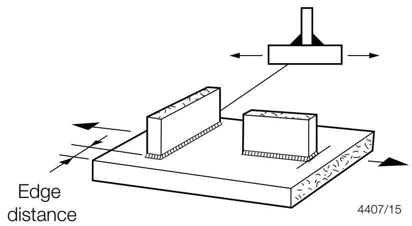
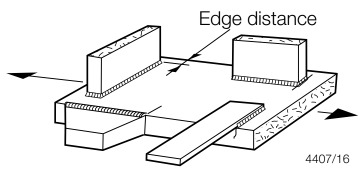
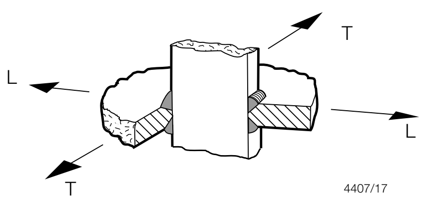
Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
3.3 Parent metal adjacent to, or weld metal in, full penetration butt welded joints made from both sides between plates of unequal width, with the weld ends ground to a radius not less than 1,25 times the thickness *t*.	F2	Step changes in width can often be avoided by the use of shaped transition plates, arranged so as to enable butt welds to be made between plates of equal width. Note that for this detail the stress concentration has been taken into account in the joint classification.	
TYPE 4 WELDED ATTACHMENTS ON THE SURFACE OR EDGE OF A STRESSED MEMBER Notes on potential modes of failure: When the weld is parallel to the direction of the applied stress, fatigue cracks normally initiate at the weld ends, but when it is transverse to the direction of stressing they usually initiate at the weld toe; for attachments involving a single, as opposed to a double, weld cracks may also initiate at the weld root. The cracks then propagate into the stressed member. When the welds are on or adjacent to the edge of the stressed member the stress concentration is increased and the fatigue strength is reduced, this is the reason for specifying an 'edge distance' in some of these joints (*see also* note on edge distance in joint Type 2).			
4.1 Parent metal (of the stressed member) adjacent to toes or ends of bevel-butt or fillet welded attachments, regardless of the orientation of the weld to the direction of applied stress and whether or not the welds are continuous round the attachment.		Butt welded joints should be made with an additional reinforcing fillet so as to provide a similar toe profile to that which would exist in a fillet welded joint.	
(a) With attachment length (parallel to the direction of the applied stress) ≤ 150 mm and with edge distance ≥ 10 mm.	F	The decrease in fatigue strength with increasing attachment length is because more load is transferred into the longer gusset giving an increase in stress concentration.	
(b) With attachment length (parallel to the direction of the applied stress) > 150 mm and with edge distance ≤ 10 mm.	F2		
4.2 Parent metal (of the stressed member) at the toes or the ends of butt or fillet welded attachments on or within 10 mm of the edge or corners of a stressed member and regardless of the shape of the attachment.	G	Note that the classification applies to all sizes of attachment. It would therefore include, for example, the junction of two flanges at right angles. In such situations a low fatigue classification can often be avoided by the use of a transition plate (*see also* joint Type 3.3).	
4.3 Parent metal (of the stressed member) at the toe of a butt weld connecting the stressed member to another member slotted through it.		Note that this classification does not apply to fillet welded joints (*see* joint Type 5.1b). However it does apply to loading in either direction (L or T in the sketch).	
(a) With the length of the slotted-through member, parallel to the direction of the applied stress, ≤150 mm and with edge distance ≥10 mm.	F		
(b) With the length of the slotted-through member, parallel to the direction of the applied stress, >150 mm and with edge distance ≥10 mm.	F2		
(c) With edge distance <10 mm.	G		

Table A3.1 **Fatigue joint classification** (*continued*)

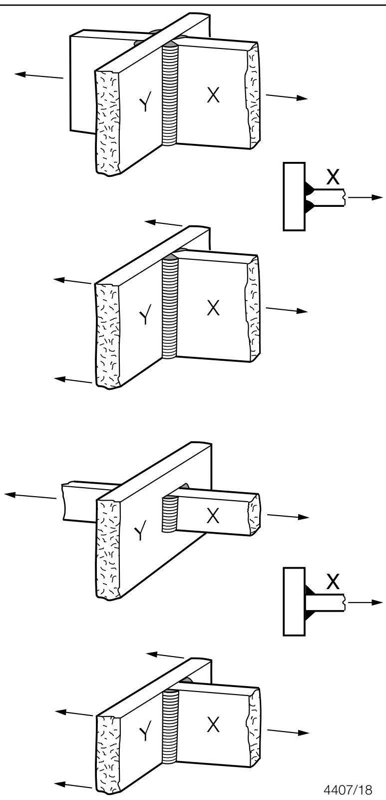
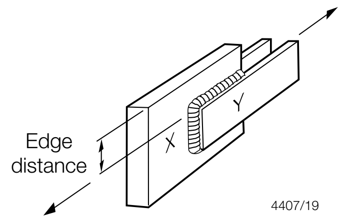
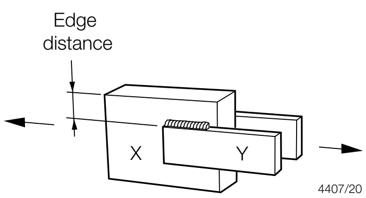
Type number, description and notes on mode of failure			Class explanatory comments	Examples, including failure modes
TYPE 5	**LOAD-CARRYING FILLET AND T BUTT WELDS**			
Notes on potential modes of failure:				
Failure in cruciform or T joints with full penetration welds will normally initiate at the weld toe, but in joints made with load-carrying fillet or partial penetration butt welds cracking may initiate either at the weld toe and propagate into the plate or at the weld root and propagate through the weld. In welds parallel to the direction of the applied stress, however, weld failure is uncommon, cracks normally initiate at the weld end and propagate into the plate perpendicular to the direction of applied stress. The stress concentration is increased, and the fatigue strength is therefore reduced, if the weld end is located on or adjacent to the edge of a stressed member rather than on its surface.				
5.1	Joint description Parent metal adjacent to cruciform joints or T joints (member marked X in sketches).		Member Y can be regarded as one with a non-load-carrying weld (*see* joint Type 4.1). Note that in this instance the edge distance limitation applies.	
(a)	Joint made with full penetration welds and with any undercutting at the corners of the member dressed out by local grinding.	F		
(b)	Joint made with partial penetration or fillet welds with any undercutting at the corners of the member dressed out by local grinding.	F2	In this type of joint, failure is likely to occur in the weld throat unless the weld is made sufficiently large (*see* joint Type 5.4).	
5.2	Parent metal adjacent to the toe of load-carrying fillet welds which are essentially transverse to the direction of applied stress (member X in sketch).		The relevant stress in member X should be calculated on the assumption that its effective width is the same as the width of member Y.	
(a)	Edge distance ≥10 mm.	F2	These classifications also apply to joints with longitudinal weld only.	
(b)	Edge distance <10 mm.	G		
5.3	Parent metal at the ends of load-carrying fillet welds which are essentially parallel to the direction of applied stress, with the weld end on plate edge (member Y in sketch).	G		
5.4	Weld metal in load-carrying joints made with fillet or partial penetration welds, with the welds either transverse or parallel to the direction of applied stress (based on nominal shear stress on the minimum weld throat area).	W	This includes joints in which a pulsating load may be carried in bearing, such as the connection of bearing stiffeners to flanges. In such examples the welds should be designed on the assumption that none of the load is carried in bearing.	

Table A3.1 Fatigue joint classification (*continued*)

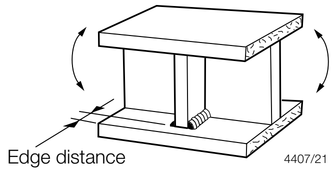
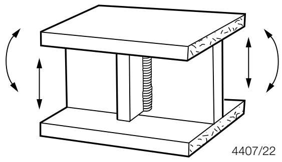
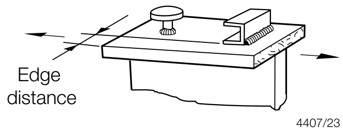
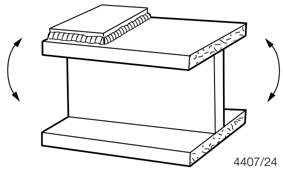
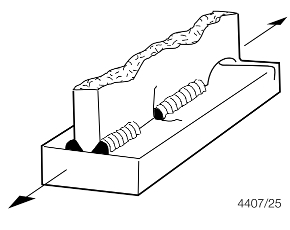
Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
TYPE 6 DETAILS IN WELDED GIRDERS Notes on potential modes of failure: Fatigue cracks generally initiate at weld toes and are especially associated with local stress concentrations at weld ends, short lengths of return welds, and changes of direction. Concentrations are enhanced when these features occur at or near an edge of a part (*see* notes on joint Type 4). General comment: Most of the joints in this section are also shown, in a more general form in joint Type 4, they are included here for convenience as being the joints which occur most frequently in welded girders.			
6.1 Parent metal at the toe of a weld connecting a stiffener, diaphragm, etc., to a girder flange. (a) Edge distance ≥10 mm (*see* joint Type 4.2). (b) Edge distance <10 mm.	F G	Edge distance refers to distance from a free, i.e. unwelded edge. In this example, therefore, it is not relevant as far as the (welded) edge of the web plate is concerned. For reason for edge distance *see* note on joint Type 2.	
6.2 Parent metal at the end of a weld connecting a stiffener, diaphragm, etc., to a girder web in a region of combined bending and shear.	E	This classification includes all attachments to girder webs.	
6.3 Parent metal adjacent to welded shear connectors. (a) Edge distance ≥10 mm. (b) Edge distance <10 mm (*see* Type 4.2).	F G		
6.4 Parent metal at the end of a partial length welded cover plate, regardless of whether the plate has square or tapered ends and whether or not there are welds across the ends.	G	This Class includes cover plates which are wider than the flange. However, such a detail is not recommended because it will almost inevitably result in undercutting of the flange edge where the transverse weld crosses it, as well as involving a longitudinal weld terminating on the flange edge and causing a high stress concentration.	
6.5 Parent metal adjacent to the ends of discontinuous welds, e.g. intermittent web/flange welds, tack welds unless subsequently buried in continuous runs. Ditto, adjacent to cope holes.	E F	This also includes tack welds which are not subsequently buried in a continuous weld. This may be particularly relevant in tack welded backing strips. Note that the existence of the cope hole is allowed for in the joint classification, it should not be regarded as an additional stress concentration.	
TYPE 7 DETAILS RELATING TO TUBULAR MEMBERS			
7.1 Parent material adjacent to the toes of full penetration welded nodal joints.	T	In this situation design should be based on the hot spot stress as defined in Ch 5,5 (*see also* this Section for guidance on partial penetration welds).	

Table A3.1 Fatigue joint classification (*continued*)

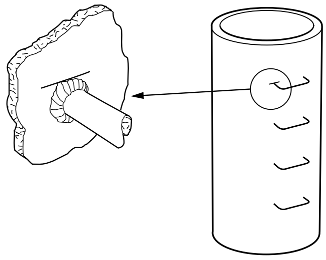
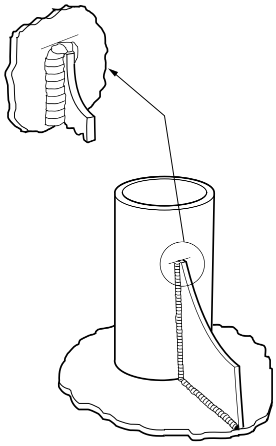
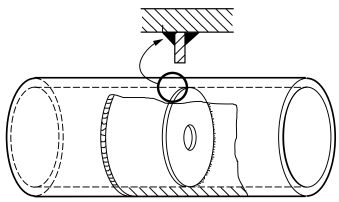
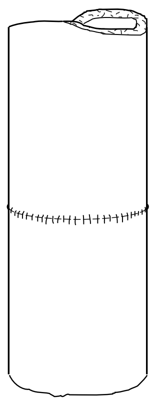
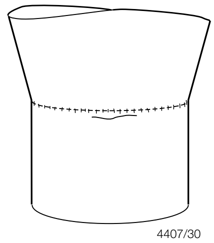
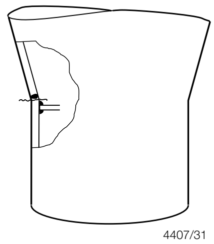
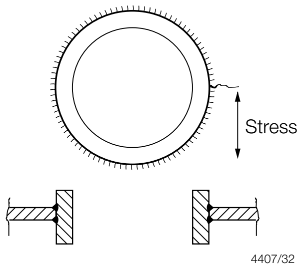
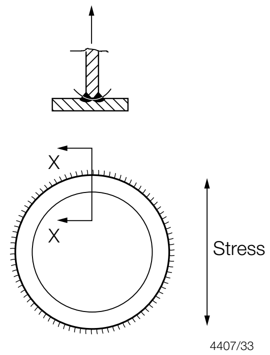
Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
7.2 Parent metal at the toes of welds associated with small (≤150 mm in the direction parallel to the applied stress) attachments to the tubular member.	F		 4407/26
As above, but with attachment length >150 mm.	F2		
7.3 Gusseted connections made with full penetration or fillet welds. (But note that full penetration welds are normally required).	F	Note that the design stress must include any local bending stress adjacent to the weld end.	 4407/27
	W	For failure in the weld throat of fillet welded joints.	
7.4 Parent material at the toe of a weld attaching a diaphragm or stiffener to a tubular member.	F	Stress should include the stress concentration factor due to overall shape of adjoining structure.	 4407/28
7.5 Parent material adjacent to the toes of circumferential butt welds between tubes.		In this type of joint the stress should include the stress concentration factor to allow for any thickness change and for fabrication tolerances.	 4407/29
(a) Welds made from both sides with the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination.	C	The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique should be selected with a view to ensuring the detection of such significant defects.	
(b) Weld made from both sides.	E		
(c) Weld made from one side on a permanent backing strip.	F		
(d) Weld made from one side without a backing strip provided that full penetration is achieved.	F2	Note that step changes in thickness are, in general, not permitted under fatigue conditions, but that where the thickness of the thicker member is not greater than 1,15 x the thickness of the thinner member, the change can be accommodated in the weld profile without any machining	

Table A3.1 Fatigue joint classification (*conclusion*)

Type number, description and notes on mode of failure		Class explanatory comments	Examples, including failure modes
7.6	Parent material at the toes of circumferential butt welds between tubular and conical section.	C E F F2	Class and stress should be those corresponding to the joint type as indicated in 7.5, but the stress must also include the stress concentration factor due to overall form of the joint.	
7.7	Parent material of the stressed member adjacent to the toes of bevel butt or fillet welded attachments in a region of stress concentration.	F or F2	Class depends on attachment length (*see* Type 4.1) but stress should include the stress concentration factor due to overall shape of adjoining structure.	
7.8	Parent metal adjacent to, or weld metal in, welds around a penetration through the wall of a member (on a plane essentially perpendicular to the direction of stress). Note that full penetration welds are normally required in this situation.	D	In this situation the relevant stress should include the stress concentration factor due to the overall geometry of the detail.	
7.9	Weld metal in partial penetration or fillet welded joints around a penetration through the wall of a member (on a plane essentially parallel to the direction of stress).	W	The stress in the weld should include an appropriate stress concentration factor to allow for the overall joint geometry.	

Section A4 Stress concentration factors

A4.1 General

A4.1.1 In general, any discontinuity in a stressed structure results in a local increase in stress at the discontinuity. The ratio of the peak stress at the discontinuity to the nominal average stress that would prevail in the absence of the discontinuity is commonly referred to as the stress concentration factor (SCF). The peak stress (i.e. nominal stress x SCF) is normally used in conjunction with an appropriate S-N curve to derive the estimated fatigue life.

A4.1.2 The design weld S-N curves are given in Section A2 for the particular joint arrangements given in Section A3.

A4.1.3 Stress concentration factors may be derived using a number of different methods, such as finite element techniques, closed form analytical formula or from model tests. For complex arrangements, a detailed finite element based analysis will most likely be required.

A4.1.4 For semi-submersible units, experience has shown that the areas of minimum fatigue life are usually found at the joints, stiffener terminations, penetrations in primary bracings and also at their junctions with hull, columns and decks. For jack-up structures locations of minimum fatigue life are usually found on the lattice legs and support structure. Other structures subjected to significant cylic loading also require assessment.

A4.1.5 Stress concentration factors for tubular brace to chord connections may be determined from LR's technical report prepared for the UK HSE, *OTH 91-353 Stress Concentration Factors for Tubular Complex Joints,* or an equivalent standard.

A4.1.6 Where finite element methods are used to determine local stress distributions for fatigue assessment, the geometric hot spot stress should account for the effect of structural discontinuities, excluding the presence of the weld. Misalignment of structural members should be accounted for where applicable.

A4.1.7 Linear extrapolation over reference points at 0,5 and 1,5 x plate thickness away from the point of interest (normally the weld toe) may be made to determine the geometric hot spot stress.

A4.1.8 In general, the geometric hot spot stress can be used in conjunction with the D class S-N curve given in Fig. A2.2.

A4.1.9 The maximum fabrication axial misalignment for fatigue prone locations would normally be limited to the smaller of 0,1 x t or 3 mm.

where

t = thickness of thinner plate

For this guidance, it may be assumed that the effects of these maximum fabrication misalignments are included within the S-N classification. Angular misalignment is to be mutually agreed between the designer and the fabricator, and is to be acceptable to LR.

Rules and Regulations for the Classification of Offshore Units

Part 5
Main and Auxiliary Machinery

July 2014

Lloyd's Register

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■ *Section 1* General

1.1 Application

1.1.1 General requirements for the design and construction of main and auxiliary machinery are given in Pt 5, Ch 1 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

1.1.2 Additional requirements with respect to unit types as indicated in this Chapter should also be complied with, as applicable.

1.2 Survey for classification

1.2.1 The Surveyors are to examine and test the materials and workmanship from the commencement of work until the final test of the machinery under full power working conditions. Any defects, etc., are to be indicated as early as possible. On completion, the Surveyors will submit a report and if this is found to be satisfactory by the Classification Committee, a certificate will be granted and an appropriate notation will be assigned in accordance with Pt 1, Ch 2.

1.3 Alternative system of inspection

1.3.1 Where items of machinery are manufactured as individual or series produced units, the Classification Committee will be prepared to give consideration to the adoption of a survey procedure based on quality assurance concepts, utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

1.3.2 In order to obtain approval, the requirements of Section 6 are to be complied with.

1.4 Departures from the Rules

1.4.1 Where it is proposed to depart from the requirements of the Rules, the Classification Committee will be prepared to give consideration to the circumstances of any special case.

1.4.2 Any novelty in the construction of the machinery, boilers or pressure vessels is to be reported to the Classification Committee.

■ *Section 2* Operating conditions

2.1 Inclination of unit

2.1.1 Main and essential auxiliary machinery is to operate satisfactorily under the conditions as shown in Table 1.2.1, Table 1.2.2 or Table 1.2.3.

Table 1.2.1 Inclination of ship units and other surface type units

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartships		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the unit	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5	22,5	10	10

NOTES
1. Athwartships and fore-and-aft inclinations may occur simultaneously.
2. Where the length of the unit exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$$\frac{500}{L} \text{ degrees}$$

where
L = length of unit, in metres, *see* Pt 4, Ch 1,5.

2.1.2 Any proposal to deviate from the angles given in Table 1.2.1, Table 1.2.2 or Table 1.2.3 will be specially considered taking into account the type, size and service conditions of the unit.

2.1.3 The dynamic angles of inclination in Table 1.2.1, Table 1.2.2 or Table 1.2.3 may be exceeded in certain circumstances, dependent upon type of unit and operation. The Builder is, therefore, to ensure that the machinery is capable of operating under these angles of inclination.

Table 1.2.2 Inclination of column-stabilised units

Installations, components	Angle of inclination in any direction, degrees	
	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the unit	15	22,5
Ballast system, emergency machinery and equipment fitted in accordance with statutory requirements	22,5	22,5

Table 1.2.3 Inclination of self-elevating units

Installations, components	Angle of inclination in any direction, degrees	
	Static	Dynamic
Main and auxiliary machinery and equipment essential to the propulsion and safety of the unit	10	15
Emergency machinery and equipment fitted in accordance with statutory requirements	15	15

■ *Section 3* Machinery room arrangements

3.1 Accessibility

3.1.1 Accessibility for attendance and maintenance purposes is to be provided for machinery plants.

3.2 Machinery fastenings

3.2.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the unit's structure to the satisfaction of the Surveyor.

3.3 Resilient mountings

3.3.1 The dynamic angles of inclination in Table 1.2.1, Table 1.2.2 or Table 1.2.3 may be exceeded in certain circumstances dependent upon unit type and operation. The Builder is, therefore, to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the conditions of maximum dynamic inclinations to be expected during service, start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

3.3.2 Anti-collision chocks are to be fitted together with positive means to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

3.3.3 A plan showing the arrangement of the machinery together with documentary evidence of the foregoing is to be submitted.

3.4 Ventilation

3.4.1 All spaces including engine and cargo pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions. *See also* Pt 7, Ch 2.

3.4.2 Machinery spaces shall be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for the operation of the machinery.

3.5 Fire protection

3.5.1 All surfaces of machinery where the surface temperature may exceed 220°C and where impingement of flammable liquids may occur are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil, the insulation is to be encased in steel or equivalent.

3.6 Means of escape

3.6.1 For means of escape from machinery spaces, *see* Pt 7, Ch 3.

3.7 Communications

3.7.1 Two independent means of communication are to be provided between the bridge and engine room control station from which the engines are normally controlled, *see also* Pt 6, Ch 1,2.

3.7.2 One of these means is to indicate visually the order and response, both at the engine room control station and on the bridge.

3.7.3 At least one means of communication is to be provided between the bridge and any other control position(s) from which the propulsion machinery may be controlled.

3.8 Category A machinery spaces

3.8.1 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:
(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or oil fuel unit.

■ *Section 4* Trials

4.1 Inspection

4.1.1 Tests of components and trials of machinery, as detailed in the Chapters giving the requirements for individual systems, are to be carried out to the satisfaction of the Surveyors.

4.2 Sea trials

4.2.1 For all types of installation, the sea trials are to be of sufficient duration, and carried out under normal manoeuvring conditions, to prove the machinery under power. The trials are also to demonstrate that any vibration which may occur within the operating speed range is acceptable.

4.2.2 The trials are to include demonstrations of the following:
(a) The adequacy of the starting arrangements to provide the required number of starts of the main engines.
(b) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the unit to rest from maximum service speed. Results of the trials are to be recorded.
(c) In turbine installations, the ability to permit astern running at 70 per cent of the full power ahead revolutions without adverse effects. This astern trial need only be of 15 minutes' duration, but may be extended to 30 minutes at the Surveyor's discretion.

4.2.3 Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern position. Where emergency manual pitch setting facilities are provided, their operation is to be demonstrated to the satisfaction of the Surveyors.

4.2.4 In geared installations, prior to full power sea trials, the gear teeth are to be suitably coated to demonstrate the contact markings, and on conclusion of the sea trials all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth. The marking is to indicate freedom from hard bearing, particularly towards the ends of the teeth, including both ends of each helix where applicable. The contact is to be not less than that required by Ch 5,4.2 or Ch 5,5.2, as applicable.

4.2.5 The following information is to be available on board for the use of the Master and designated personnel:
- The results of trials to determine stopping times, unit headings and distance;
- For units having multiple propellers, the results of trials to determine the ability to navigate and manoeuvre with one or more propellers inoperative.
- For units having a single propulsor driven by multiple engines or electric motors, the results of trials to determine the ability to navigate and manoeuvre with the largest engine or electric motor inoperative.

4.2.6 Where the unit is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means is to be demonstrated and recorded as referred to in 4.2.5.

4.2.7 The stopping distance achieved when the unit is initially proceeding ahead with a speed of at least 90 per cent of the unit's speed corresponding to 85 per cent of the maximum rated propulsion power, should not exceed 15 unit lengths after the astern order has been given. However, if the displacement of the unit makes this criterion impracticable then in no case should the stopping distance exceed 20 unit lengths.

4.2.8 All trials are to be to the Surveyor's satisfaction.

■ *Section 5* Quality Assurance Scheme for Machinery

5.1 General

5.1.1 This certification scheme is applicable to both individual and series produced items manufactured under closely controlled conditions and will be restricted to works where the employment of quality control procedures is well established. LR will have to be satisfied that the practices employed will ensure that the quality of finished products is to standards which would be demanded when using traditional survey techniques.

5.1.2 The Classification Committee will consider proposed designs for compliance with LR's Rules or other appropriate requirements and the extent to which the manufacturing processes and control procedure ensure conformity of the product to the design. A comprehensive survey will be made by the Surveyors of the actual operation of the quality control programme and of the adequacy and competence of the staff to implement it.

5.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

5.1.4 Approval by another organisation will not be accepted as sufficient evidence that a manufacturer's arrangements comply with LR's requirements.

5.2 Requirements for approval

5.2.1 **Facilities**. The manufacturer is required to have adequate equipment and facilities for those operations appropriate to the level of design, development and manufacture being undertaken.

5.2.2 **Experience**. The manufacturer is to demonstrate that the firm has experience consistent with technology and complexity of the product type for which approval is sought and that the firm's products have been of a consistently high standard.

5.2.3 **Quality policy**. The manufacturer is to define management policies and objectives or quality and ensure that these policies and objectives are implemented and maintained throughout all phases of the work.

5.2.4 **Quality system documentation**. The manufacturer is to establish and maintain a documented quality system capable of ensuring that material or services conform to the specified requirements, including the requirements of this Section.

5.2.5 **Management representative**. The manufacturer is to appoint a management representative, preferably independent of other functions, who is to have defined authority and responsibilities for the implementation and maintenance of the quality system.

5.2.6 **Responsibility and authority**. The responsibilities and authorities of senior personnel within the quality system are to be clearly documented.

5.2.7 **Internal audit**. The manufacturer is to conduct internal audits to ensure continued adherence to the system. An audit programme is to be established with audit frequencies scheduled on the basis of the status and importance of the activity and adjusted on the basis of previous results.

5.2.8 **Management review**. The quality system established in accordance with the requirements of this Section is to be systematically reviewed at appropriate intervals by the manufacturer to ensure its continued effectiveness. Records of such management reviews are to be maintained and be made available to the Surveyors.

5.2.9 **Contract review**. The manufacturer is to establish and implement procedures for conducting a contract review prior to and after acceptance to ensure that:

(a) the requirements of the contract are adequately defined and documented;
(b) any requirements differing from those specified in the original enquiry/tender are resolved; and
(c) the manufacturer has the capability to meet and verify compliance to the specified requirements.

5.2.10 **Work instruction**. The manufacturer is to establish and maintain clear and complete written work instructions that prescribe the communication of specified requirements and the performance of work in design, development and manufacture which would be adversely affected by lack of such instructions.

5.2.11 **Documentation and change control**. The manufacturer is to establish and maintain control of all documentation that relates to the requirements of this scheme. This control is to ensure that:

(a) documents are reviewed and approved for adequacy by authorised personnel prior to use, are uniquely identified and include indication of approval and revision status;
(b) all changes to documentation are in writing and are processed in a manner that will ensure their availability at the appropriate location and preclude the use of non-applicable documents;
(c) provision is made for the prompt removal of obsolete documentation from all points of issue or use; and
(d) documents are to be re-issued after a practical number of changes have been issued.

5.2.12 **Records**. The manufacturer is to develop and maintain a system for collection, use and storage of quality records. The period of retention of such records is to be established in writing and is to be subject to agreement by the Classification Committee.

5.2.13 **Design**. The manufacturer is to establish and maintain a design control system appropriate to the level of design being undertaken. Documented design procedures are to be established which:

(a) identify the design practices of the manufacturer's organisation including departmental instructions to ensure the orderly and controlled preparation of design and subsequent verification;
(b) make provision for the identification, documentation and appropriate approval of all design change and modifications;
(c) prescribe methods for resolving incomplete, ambiguous or conflicting requirements; and
(d) identify design inputs such as sources of data, preferred standard parts or materials and design information and provide procedures for their selection and review by the manufacturer for adequacy.

5.2.14 **Purchasing**. The manufacturer is to ensure that purchased material and services conform to specified requirements.

5.2.15 **Selection and approval of sub-contractors and suppliers**. The manufacturer is to establish and maintain records of acceptable suppliers and sub-contractors. The selection of such sources, and the type and extent of control exercised, are to be appropriate to the type of product or service and the suppliers' or sub-contractors' previously demonstrated capability and performance. Documented procedures for approval of new suppliers are to be established and records of vendor assessments (where carried out) are to be maintained and made available to the Surveyors upon request.

5.2.16 **Purchasing data**. Each purchasing document should contain a clear description of the material or service ordered, including, as applicable, the following:

(a) The type, class, grade, or other precise identification;
(b) The title or other positive identification and applicable issue of specifications, drawings, process requirements, inspection instructions and other relevant data.

5.2.17 **Verification of purchased material and services**. The manufacturer is to ensure that the Surveyors are afforded the right to verify at source or upon receipt that purchased material and services conform to specified requirements. Verification by the Surveyors shall not relieve the manufacturer of his responsibility to provide acceptable material nor is it to preclude subsequent rejection.

5.2.18 **Product identification**. The manufacturer is to establish and maintain a system for identification of the product to relevant drawings, specifications or other documents during all stages of production, delivery and installation.

5.2.19 **Manufacturing control**. The manufacturer is to ensure that those operations which directly affect quality are carried out under controlled conditions. These are to include the following:

(a) Written work instructions wherever the absence of such instructions could adversely affect compliance with specified requirements. These should define the method of monitoring and control of product characteristics.
(b) Established criteria for workmanship through written standards or representative samples.

5.2.20 **Special processes**. Those processes where effectiveness cannot be verified by subsequent inspection and test of the product are to be subjected to continuous monitoring in accordance with documented procedures, in addition to the requirements specified in 6.2.19.

5.2.21 **Receiving inspection**. The manufacturer is to ensure that all incoming material is not to be used or processed until it has been inspected or otherwise verified as conforming to specified requirements. In establishing the amount and nature of receiving inspection, consideration is to be given to the control exercised by the supplier and documented evidence of quality conformance supplied.

5.2.22 **In-process inspection**. The manufacturer is to:

(a) perform inspection during manufacture on all characteristics that cannot be inspected at a later stage;
(b) inspect, test and identify products in accordance with specified requirements;
(c) establish product conformance to specified requirements by use of process monitoring and control methods where appropriate;
(d) hold products until the required inspections and tests are completed and verified; and
(e) clearly identify non-conforming products to prevent unauthorised use, shipment, or mixing with conforming material.

5.2.23 **Final inspection**. The manufacturer is to perform all inspections and tests on the finished product necessary to complete the evidence of conformance to the specified requirements. The procedures for final inspection and test are to ensure that:

(a) all activities defined in the specification, quality plan or other documented procedure have been completed;
(b) all inspections and tests that should have been conducted at earlier stages have been completed and that the data is acceptable; and
(c) no product is to be dispatched until all the activities defined in the specifications, quality plan or other documented procedure have been completed, unless products have been released with the permission of the Surveyors.

5.2.24 **Inspection equipment.** The manufacturer is to be responsible for providing, controlling, calibrating and maintaining the inspection, measuring and test equipment necessary to demonstrate the conformance of material and services to the specified requirements or used as part of the manufacturing control system required by 5.2.19 and 5.2.20.

5.2.25 **Inspection and test status**. The manufacturer is to establish and maintain a system for the identification of inspection status of all material, components and assemblies by suitable means which distinguish between conforming, non-conforming and uninspected items. The relevant inspection and test procedures and records are to identify the authority responsible for the release of conforming products.

5.2.26 **Control of non-conforming material**.

(a) The manufacturer is to establish and maintain procedures to ensure that material that does not conform to the specified requirements is controlled to prevent inadvertent use, mixing or shipment. Repair, rework or concessions on non-conforming material and re-inspection are to be in accordance with documented procedures.
(b) Records clearly identifying the material, the nature and extent of non-conformance and the disposition are to be maintained.

5.2.27 **Sampling procedures**. Where sampling techniques are used by the manufacturer to verify the acceptability of groups of products, the procedures adopted are to be in accordance with the specified requirements or are to be subject to agreement by the Surveyors.

5.2.28 **Corrective action**. The manufacturer is to establish and maintain documented procedures for the review of non-conformances and their disposition. These should provide for:

(a) monitoring of process and work operations and analysis of records to detect and eliminate potential causes of non-conforming material;
(b) continuing analysis of concessions granted and material scrapped or reworked to determine causes and the corrective action required;
(c) an analysis of customer complaints;
(d) the initiation of appropriate action with suppliers or subcontractors with regard to receipt of non-conforming material; and
(e) an assurance that corrective actions are effective.

5.2.29 **Purchaser supplied material**. The manufacturer is to establish and maintain documented procedures for the control of purchaser supplied material.

5.2.30 **Handling, storage, and delivery**:
(a) The manufacturer is to establish and maintain a system for the identification preservation, segregation and handling of all material from the time of receipt through the entire production process. The system is to include methods of handling that prevent abuse, misuse, damage or deterioration.
(b) Secure storage areas or rooms are to be provided to isolate and protect material pending use. To detect deterioration at an early stage, the condition of material is to be periodically assessed.
(c) The manufacturer is to arrange for the protection of the quality of his product during transit. The manufacturer is to ensure, in so far as it is practicable, the safe arrival and ready identification of the product at destination.

5.2.31 **Training**. The manufacturer is to follow a policy for recruitment and training which provides an adequate labour force with such skills as are required for each type of work operation. Appropriate records are to be maintained to demonstrate that all personnel performing process control, special processes inspection and test or quality system maintenance activities have appropriate experience or training.

5.3 Arrangements for acceptance and certification of purchased material

5.3.1 The manufacturer is to establish and maintain procedures and controls to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant. The manufacturer's system for control of such purchased material may be based on one of the following alternatives, subject to the approval of LR:
(a) Product certification by LR's Surveyors at the supplier's works in accordance with the requirements of the Rules for Materials.
(b) Agreed Inspection Procedures at the manufacturer's plant combined with documentary evidence of vendor assessments, vendor rating records and annual surveillance visits to the suppliers.
(c) Recognition of quality agreements between the manufacturer and his suppliers which are to provide for initial vendor assessments and regular surveillance visits (a minimum of four per year). The quality agreement must identify the individual in the supplier's plant who is charged with the responsibility for release of materials or components and the procedures to be adopted.

5.3.2 The alternatives proposed in 5.3.1(b) and (c) are not acceptable to LR for the following items:
(a) Engine components for which testing is a Rule requirement; and
  (i) the cylinder bore is equal to or exceeds 300 mm; or
  (ii) which are made by open forging techniques.
(b) Cast crankshafts where the journal diameter exceeds 85 mm.

5.3.3 Where the manufacturer's system for control of purchased material is based upon 6.3.1(b) or (c), the Surveyors shall also make surveillance visits to the supplier's works at the minimum specified intervals. The manufacturer is also to make available to the Surveyors documentary evidence of the operation of quality agreements or Agreed Inspection Procedures where applicable.

5.4 Information required for approval

5.4.1 Manufacturers applying for approval under this scheme are to submit the following information:
(a) A description of the products for which certification is required including, where applicable, model or type number.
(b) Applicable plans and details of material used.
(c) An outline description of all important manufacturing plant and equipment.
(d) A summary of equipment used for measuring and testing during manufacture and completion.
(e) The Quality Manual.
(f) A typical production flow chart and quality plan covering all stages from ordering of materials to delivery of the finished product.
(g) The system used for the identification of raw materials, semi-finished and finished products.
(h) The number and qualifications of all staff engaged in testing, inspection and quality control duties.
(j) A list of suppliers of components and manufacturers, proposed procedures to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant.

5.5 Assessment of works

5.5.1 After receipt and appraisal of the information requested in 5.4, an inspection of the works is to be carried out by the Surveyors to examine in detail all aspects of production, and in particular the arrangements for quality control.

5.5.2 The Surveyors will not specify in detail acceptable quality control procedures, but will consider the arrangements proposed by the works in relation to the manufacturing processes and products.

5.5.3 In the event of procedures being considered inadequate, the Surveyors will advise the manufacturer how such procedures are to be revised in order to be acceptable to LR.

5.5.4 Gauging, measuring and testing devices are to be made available to the Surveyors, and where appropriate, personnel for the operation of such devices.

5.6 Approval of works

5.6.1 If the initial assessment of the works confirms that the manufacturing and quality control procedures are satisfactory, the Classification Committee will issue to the manufacturer a Quality Assurance Approval Certificate which will include details of the products for which approval has been given. This Certificate will be valid for three years with renewal subject to satisfactory performance and to a satisfactory triennial reassessment.

5.6.2 An extension of approval in respect of product type may be given at the discretion of the Classification Committee without any additional survey of the works.

5.6.3 LR will publish a list of manufacturers whose works have been approved.

5.7 Maintenance of approval

5.7.1 The arrangements authorised at each works are to be kept under review by the Surveyors in order to ensure that the approved procedures for manufacture and quality control are being maintained in a satisfactory manner. This is to be carried out by:

(a) regular and systematic surveillance;
(b) intermediate audits at intervals of six months;
(c) triennial reassessment of the entire quality system.

5.7.2 For the purpose of regular and systematic surveillance, the Surveyors are to visit the works at intervals determined by the type of product and the rate of production. The Surveyors are to advise a senior member of the quality control department in regard to any matter with which they are not satisfied.

5.7.3 When minor deficiencies in the approved procedures are disclosed during the systematic surveillance the Surveyors may, at their discretion, apply more intensive supervision, including the direct inspection of products.

5.7.4 Any noteworthy departures from the approved plans of specifications are to be reported to the Surveyors and their written approval obtained prior to despatch of the item.

5.7.5 Minor alterations in the approved procedures may be permitted provided that the Surveyors are advised and their prior concurrence obtained.

5.7.6 In addition to the regular visits by the Surveyors, an intermediate audit is to be carried out every six months. This will normally be carried out by Surveyors other than those regularly in attendance at the works. This audit is to consist of an examination of part of the manufacturer's quality system. An audit plan will be established indicating those areas of the quality system which will be examined during every intermediate audit and the frequency of examination of other areas such that all areas are subject to audit before re-assessment is due.

5.7.7 The manufacturer's entire quality system is to be subject to reassessment at three-yearly intervals. This is to be conducted by Surveyors nominated by LR.

5.8 Suspension or withdrawal of approval

5.8.1 When the Surveyors have drawn attention to significant faults or deficiencies in the manufacturing or quality control procedures and these have not been rectified, approval of the works will be suspended. In these circumstances, the manufacturer will be notified in writing of the Classification Committee's reasons for the suspension of approval.

5.8.2 When approval has been suspended and the manufacturer does not effect corrective measures within a reasonable time, the Classification Committee will withdraw the Quality Assurance Approval Certificate.

5.9 Identification of products

5.9.1 In addition to the normal marking by the manufacturer, all certified products are to be hard stamped on a principal component with a suitable identification, LR's brand and the number of the approved works.

5.9.2 After issue of the Quality Assurance Approval Certificate, products may be dispatched with certificates signed on behalf of the manufacturer by an authorised senior member of the quality control department or by an authorised deputy. These certificates are to be countersigned by the Surveyor to certify that the approved arrangements are being kept under review by regular and systematic auditing of the manufacturer's quality system.

5.9.3 The following declarations are to be included on each certificate:

(a) 'This is to certify that the items described above have been constructed and tested with satisfactory results in accordance with the Rules of Lloyd's Register.
Signed...
Manager of QC Department.'

(b) 'This certificate is issued by the manufacturer in accordance with the arrangements authorised by Lloyd's Register in Quality Assurance Approval Certificate No. QA.M.................................. I certify that these arrangements are being kept under review by regular and systematic auditing of the approved manufacturing and quality control procedures.
Signed..
Surveyor to Lloyd's Register'.

5.9.4 In the event of noteworthy departures from the approved plan or specification being accepted, a standard 'Concession' form is to be completed and signed by the following authorised persons: the design Manager, the Quality Control Manager or their deputies. In all cases, where strength or functioning may be affected, the form is to be submitted to the Surveyors for approval and endorsement.

Section 6
Spare gear for machinery installations

6.1 Application

6.1.1 Adequate spare parts for the propelling and essential auxiliary machinery, together with the necessary tools for maintenance and repair, are to be readily available for use.

6.1.2 The spare parts to be supplied and their location is to be the responsibility of the Owner, but they must take into account the design and arrangement of the machinery and the intended service and operation of the unit. Account must also be taken of the recommendations of the manufacturers and any applicable requirement of the relevant Administration.

6.2 Guidance for spare parts

6.2.1 For general guidance purposes, spare parts for main and auxiliary machinery installations are shown in the LR's *Spare Gear Guidance* located on Class Direct Live.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for oil engines are given in Pt 5, Ch 2 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1 General

1.1 Application

1.1.1 Requirements for steam turbines are given in Pt 5, Ch 3 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for gas turbines are given in Pt 5, Ch 4 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for machinery gearing are given in Pt 5, Ch 5 of the *Rules and Regulations for the Classification of Ships,* which should be complied with.

Section 1 General

1.1 Application

1.1.1 Requirements for main propulsion shafting are given in Pt 5, Ch 6 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for propellers are given in Pt 5, Ch 7 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Contents

Section 1
General

1.1 Application

1.1.1 Requirements for shaft vibration and alignment are given in Pt 5, Ch 8 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for podded propulsion units are given in Pt 5, Ch 9 of the *Rules and Regulations for the Classification of Ships,* which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for steam raising plant and associated pressure vessels are given in Pt 5, Ch 10 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General

1.1 Application

1.1.1 Requirements for fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not included in Chapter 10, are given in Pt 5, Ch 11 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

1.1.2 For the construction and design of pressure vessels and plate heat exchangers for liquefied gas applications, *see* Part 11.

Section

Section 1 **General**

1.1 Application

1.1.1 Requirements for piping design are given in Pt 5, Ch 12 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

■ *Section 1* General

1.1 Application

1.1.1 Requirements for bilge and ballast piping systems are given in Pt 5, Ch 13 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with.

1.1.2 Additional requirements with respect to unit types as indicated in this Chapter should also be complied with, as applicable.

■ *Section 2* Construction and installation

2.1 Valves and fittings on the side of the unit (other than those on scuppers and sanitary discharges)

2.1.1 Inlet and discharge valves in compartments situated below the assigned loadline and located in normally unattended spaces are to be provided with remote control which is capable of operating when submerged. *See also* Pt 5, Ch 13,2.5 of the Rules for Ships.

2.1.2 For column-stabilised units all sea inlet and overboard discharge valves are to be provided with remote control.

2.1.3 Where remote operation is provided by power-activated valves for sea inlets and discharges for supply to fire pumps, power supply failure of the control system is not to result in the closing of open valves or the opening of closed valves.

2.1.4 Consideration will be given to accepting bilge alarms in lieu of remote operation for surface type and self-elevating units. *See also* Section 10 and Pt 6, Ch 1.

■ *Section 3* Drainage of compartments, other than machinery spaces for column-stabilised units

3.1 General

3.1.1 Bilge systems are to be capable of operating satisfactorily under the conditions as shown in Table 1.1.2 in Chapter 1.

3.1.2 Provision is to be made for detection and drainage of leakage within main bracings that are sealed against the ingress of sea-water when submerged in operating conditions.

3.1.3 For the members mentioned in 3.1.2 and other regions of the unit, where numerous small compartments are provided, arrangements are to be made for venting, draining and sounding, except where flooding of one or more compartments will not materially affect the stability criteria. Nevertheless, provision is to be made for the detection of leakage in each compartment. In all cases, fault condition alarms are to be provided at the central control station.

3.1.4 Special consideration is to be given to the design and workmanship of fittings and penetrations in the bracings. *See* Pt 4, Ch 8,5.

■ *Section 4* Additional bilge drainage requirements for column-stabilised units and self-elevating units

4.1 Location of bilge pumps and bilge main

4.1.1 In accommodation units, the power bilge pumps required by Pt 5, Ch 13,6.1.5 of the Rules for Ships are to be placed, if practicable, in separate watertight compartments which will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as is possible. *See also* Pt 5, Ch 13,6.1.7 of the Rules for Ships.

4.1.2 In accommodation units of 91,5 m or more in length, or having a bilge pump numeral of 30 or more, *see* Pt 5, Ch 13,6.1.5 and 6.1.7 of the Rules for Ships, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the unit may be flooded at sea. This requirement will be satisfied if:

- one of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck; or
- the pumps and their sources of power are so disposed throughout the length of the unit that, under any conditions of flooding which the unit is required by statutory regulation to withstand, at least one pump in an undamaged compartment will be available.

4.1.3 The bilge main is to be so arranged that no part is situated nearer the side of the unit than *B*/5, measured at right angles to the centreline at the level of the deepest subdivision load line, where *B* is the breadth of the unit.

4.1.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the *B*/5 line, a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be so arranged that they are situated inboard of the *B*/5 line.

4.2 Prevention of communication between compartments in the event of damage

4.2.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the unit than *B*/5 or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

4.3 Arrangement and control of bilge valves

4.3.1 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from the bulkhead deck. Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case, only the valves and cocks necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

4.3.2 All valves and cocks in 4.3.1 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

4.4 Cross-flooding arrangements

4.4.1 Where divided deep tanks or side tanks are provided with cross-flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross-flooding fittings are provided, they are to be operable from above the bulkhead deck. Additional bilge drainage requirements for column-stabilised units and self-elevating units are given in 4.5 to 4.7.

4.5 General

4.5.1 The bilge system is to be capable of operating satisfactorily under the conditions specified in Table 1.1.2 or 1.1.3 in Chapter 1.

4.5.2 Dry compartments below the lowest continuous deck on self-elevating units, and below the main deck on column-stabilised units, containing essential equipment for the operation and safety of the unit, or providing essential buoyancy, are to have a permanently installed bilge pumping system.

4.5.3 Where the open drain pipe is carried through a watertight bulkhead or deck, it is to be fitted with an easily accessible self-closing valve at the bulkhead or deck, or a valve capable of being closed from above the damage waterline.

4.5.4 A mimic panel showing all the compartments and arrangements of the bilge and drainage systems is to be suitably positioned at the central control station.

4.6 Column-stabilised units

4.6.1 At least one of the pumps referred to in Pt 5, Ch 13,6 of the Rules for Ships is to be arranged solely for bilge pumping duties. This pump and the pump-room bilge suction valves are to be capable of both remote and local operation.

4.6.2 Propulsion rooms and pump-rooms in lower hulls, which are normally unattended, are to be provided with two independent systems for bilge water high level detection, providing an audible and visual alarm at the central control station.

4.6.3 Chain lockers which, if flooded, could substantially affect the unit's stability are to be provided with a remote means to detect flooding, a permanently installed means of dewatering and remote indication provided at the central control station. The dewatering system is to be independent of the main bilge system and the pumps are to have adequate reserve capacity to keep the chain locker empty in any damage condition. The minimum discharge capacity of the pumps is not to be less than the flow rate calculated using the internal diameter of the chain pipe when subjected to a head of water measured from the top of the chain pipe to the 4 m waterline defined in Pt 4, Ch 7,4.7.2.

4.7 Self-elevating units

4.7.1 The bilge system is to be arranged so that essential compartments such as machinery and pump-rooms can be emptied even when the unit is in the flooded condition. The control and position indication system for the bilge valves is to be suitable for operation if the equipment should become submerged.

4.7.2 At least one of the pumps referred to in Pt 5, Ch 13,6 of the Rules for Ships is to be arranged solely for bilge pumping duties.

4.7.3 Chain lockers, if fitted, may be emptied by means of portable pumps or permanently installed pumps or ejectors. Where the utilisation of portable pumps is intended, two units are to be carried on board.

■ *Section 5* Ballast system

5.1 General requirements

5.1.1 Units are to be provided with an efficient pumping system capable of ballasting and de-ballasting any ballast tank under normal operating and transit conditions. The system is to be arranged to prevent inadvertent transfer of ballast from one tank or hull to another.

5.1.2 The ballast system is to be arranged so that it will remain operable, and tanks can be effectively de-ballasted through at least one suction, up to angles of inclination as specified in Tables 1.1.1, 1.1.2 and 1.1.3 in Chapter 1, as applicable.

5.1.3 The system is to be designed so that a single failure or mal-operation of any item of equipment or component will not lead to uncontrolled liquid movement. Pumps, piping and control systems should not be situated within the defined damage penetration zones, *see* Pt 5, Ch 13,1.2 of the Rules for Ships.

5.2 Pumps

5.2.1 At least two independently driven ballast pumps are to be provided and arranged so that the system will remain operable in the event of failure of any one pump. Consideration should be given to locating the pumps in separate compartments where, in the event of flooding, fire or other damage in a particular compartment, an alternative pump in an unaffected compartment will be available. Such pumps need not be dedicated ballast pumps, but must be readily available for use on the ballast system at all times.

5.2.2 The capacity of each ballast pump is to be sufficient to provide safe handling and operation of the unit.

5.2.3 Ballast pumps should be self-priming unless it can be demonstrated that this would be unnecessary for the intended application. Pumps of the centrifugal type are to be self-priming by means of an automatic priming system.

5.3 Piping and valves

5.3.1 Ballast pipes are to be of steel or other approved material. Special consideration should be given to the design of pipes passing through tanks, particularly with regard to the effects of corrosion.

5.3.2 All valves are to be clearly marked to identify their function. Positive indication (open/closed) is to be provided at the valve, and at all positions from which the valve can be controlled. The indicators are to rely on the movement of the valve spindle.

5.3.3 The valves in the ballast system are to be self-closing by mechanical means or be power-operated by either a stored energy system provided with no fewer than two power units, or by an electrical supply system. Consideration should also be given to the need for equipment to operate when submerged.

5.3.4 The closing speed of power-operated valves should be limited where necessary, to prevent excessive pressure surges.

5.3.5 Valves which fail to set position are to be provided with an independent secondary means of closure from a readily accessible position above the damage waterplane. Power failure to sea-water inlet and discharge valves for systems such as cooling for essential machinery or for supply to fire pumps should not result in closing of open valves or in opening of closed valves. Such systems, which require the inlet/discharge valve to fail to a set position, are not to share a common inlet/discharge with systems in which the valves fail closed.

5.3.6 All sea inlet and discharge valves which are submerged at maximum operating draught and are located in normally unattended spaces are to be remotely controlled from a manned control station. Such valves are to fail automatically to the closed position on loss of control or actuating power unless overriding considerations require a valve to fail to set position.

5.4 Control of pumps and valves

5.4.1 All ballast pumps and power-operated valves are to be fitted with independent local control, which may be manual control, in addition to the remote control from the central control station. The independent local control of each ballast pump and of its associated tank valves should be in the same location. Such local controls are to be readily accessible and, where practicable, their access routes should not be situated within the defined damage penetration zones, *see* Pt 5, Ch 13,1.2 of the Rules for Ships. A diagram of the representative part of the ballast system is to be permanently displayed at each location.

5.4.2 The control systems are to function independently of the indicating systems, or have sufficient redundancy, such that failure of one system does not jeopardise the operation of the other systems.

5.4.3 Valves which have failed closed should, on restoration of power, remain closed until the operator assumes control of the reactivated system.

5.4.4 For requirements relating to control and supervision of unattended ballast pumps located in dangerous or hazardous spaces, *see* Pt 7, Ch 2,5.1.8.

5.5 Column-stabilised units

5.5.1 The general requirements of 5.1 to 5.4 are to be complied with unless otherwise specified in this Section.

5.5.2 The ballast system is to have the capability to bring the unit, while in an intact condition, from the maximum normal operating draught to a severe storm draught or a decrease in draught of 4,6 m, whichever distance is greater, within three hours.

5.5.3 In the damage condition, *see* Pt 4, Ch 7, the system is to have the capability of restoring the unit to a level trim and safe draught condition without taking additional ballast and with any one pump inoperable.

5.5.4 The ballast system sea-water inlets and discharges should be separate from those of other systems.

5.5.5 Ballast system manifolds are to be arranged such that a specially defined operational procedure must be carried out when ballast is transferred from one end or side of the unit to the other.

■ *Section 6*
Air, overflow and sounding pipes for column-stabilised units

6.1 Size of air pipes

6.1.1 For each ballast tank, air pipes of sufficient size and number are to be provided to permit the efficient operation of the ballast pumping system under conditions referred to in 5.1. To allow de-ballasting of tanks intended to be used to bring the unit back to normal draught, and to ensure no inclination after damage, air pipe openings are to be above the worst damage waterline, and positioned outside the defined damage penetration zones, *see* Pt 4, Ch 7,4.

6.2 Sounding arrangements

6.2.1 Ballast tanks are to be provided with sounding pipes or other suitable sounding devices which are separate and additional to any remote sounding systems. The soundings are to be taken as near to the suction pipes as practicable. Where remote sounding systems are fitted, the indications are to be located in the central control station.

Section

■ *Section 1* General

1.1 Application

1.1.1 Requirements for machinery piping systems are given in Pt 5, Ch 14 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with.

1.1.2 Additional requirements in this Chapter should also be complied with, as applicable.

■ *Section 2* Helicopter refuelling facilities

2.1 Fuel storage

2.1.1 Storage tanks and skids are to be located in a designated area as remote as practicable from machinery and accommodation spaces, escape routes and embarkation stations and are to be suitably isolated from areas where there are sources of ignition.

2.1.2 The storage and handling area is to be permanently marked. Instructions for filling fuel are to be posted in the vicinity of the filling area.

2.1.3 The tanks are to be protected from helicopter crashes, mechanical damage, solar and flare radiation and high temperatures as a result of a fire occurring in an adjacent area.

2.1.4 Tanks are to be of approved metallic construction and special attention is to be given to the inspection procedures, mounting and securing arrangements and electrical bonding of the tank and fuel transfer system. Transportable tanks shall be specially designed for their intended use and equipped with suitable fittings, lifting and fixing arrangements and earthing, and are to comply with the relevant Codes for the transportation of dangerous goods in ships.

2.1.5 Tank ventilation pipes are to be fitted with an approved type of vent head with pressure-vacuum valve and flame arrester. The vent outlet is to be located in a safe position away from accommodation spaces and ventilation intakes.

2.1.6 The fuel storage area is to be provided with a collecting tray of suitable capacity for containing leakage from the tanks and pumping units, and for draining any such leakage to a tank or container located in a safe area. For tanks forming an integral part of the unit's structure, cofferdams are to be provided as necessary to contain leakage and prevent contamination of the fuel.

2.2 Fuel pumping and filling

2.2.1 The tank outlet valve is to be mounted directly onto the tank and shall be capable of being closed from a remote location in the event of fire. Ball valves are to be stainless steel, anti-static, fire-tested type.

2.2.2 The pumping unit is to be connected to only one tank at a time. Pipes between the tanks and the pumping unit are to be of stainless steel or equivalent material, or flexible hoses of an approved type, fire-tested to an acceptable National Standard. Such pipes or hoses are to be protected from mechanical damage and be as short as possible. Where a flexible hose is used to connect the pumping unit to a tank, the hose connection is to be of the quick-disconnect, self-closing type.

2.2.3 Pumping units are to be capable of being controlled from the refuelling station.

2.2.4 Pumping units are to incorporate a device to prevent over-pressurisation of the filling hose.

2.2.5 Arrangements for fuel metering and sampling are to be provided.

■ *Section 3* Requirements for boilers and heaters

3.1 Scope

3.1.1 In the context, the term'boilers' also includes steam boilers, Glycol/Amine/Selexol, etc., reboilers and thermal oil heaters, which are fired units.

3.2 General

3.2.1 For all fired boilers, the pre-purge is to be sufficient to give at least 5 air changes in the furnace and/or at least 2,5 complete air changes of the furnace and uptakes, whichever is greater.

3.2.2 Combustion air is to be taken from a safe area.

3.2.3 Gas detectors are to be fitted in the combustion air intake trunking, that will shut down the boiler and alarm at a manned station.

3.2.4 Gas-fired boilers are to be fitted with fuel oil pilot igniter system. A fuel gas system or electric spark ignition for the main burner are not acceptable systems.

3.2.5 Boilers are to be located in areas designated 'safe areas'. If the boiler cannot be fitted in an area designated 'safe area' then it must be fitted with the following:

(a) The furnace must be a closed front type.
(b) The combustion air must be ducted from an area designated a 'safe area' and fitted with a flame arrestor.
(c) The combustion air intake is to be fitted with a gas detector which will alarm and shut down the flame on gas detection.
(d) A gas detector is to be fitted near to the boiler in the compartment in which the boiler is located.
(e) The maximum surface temperatures as given in the Rules are to be complied with.

3.2.6 Fig. 14.3.1 shows a typical arrangement for a boiler room.

3.2.7 For boilers that use fuel gas, *see* Pt 5, Ch 16 as applicable.

3.2.8 For boilers located in a safe area, combustion air may be taken from the boiler compartment.

3.2.9 Boiler compartment ventilation is to be a minimum of 12 air changes per hour.

3.2.10 All boilers are to be fitted with a method of leak detection depending upon the fluid contained in the boiler. Adequate leak collection and drainage is to be provided.

3.3 Thermal oil boilers/heaters

3.3.1 The requirements for thermal oil boilers and heaters are given in Pt 5, Ch 15,6.5 of the Rules for Ships.

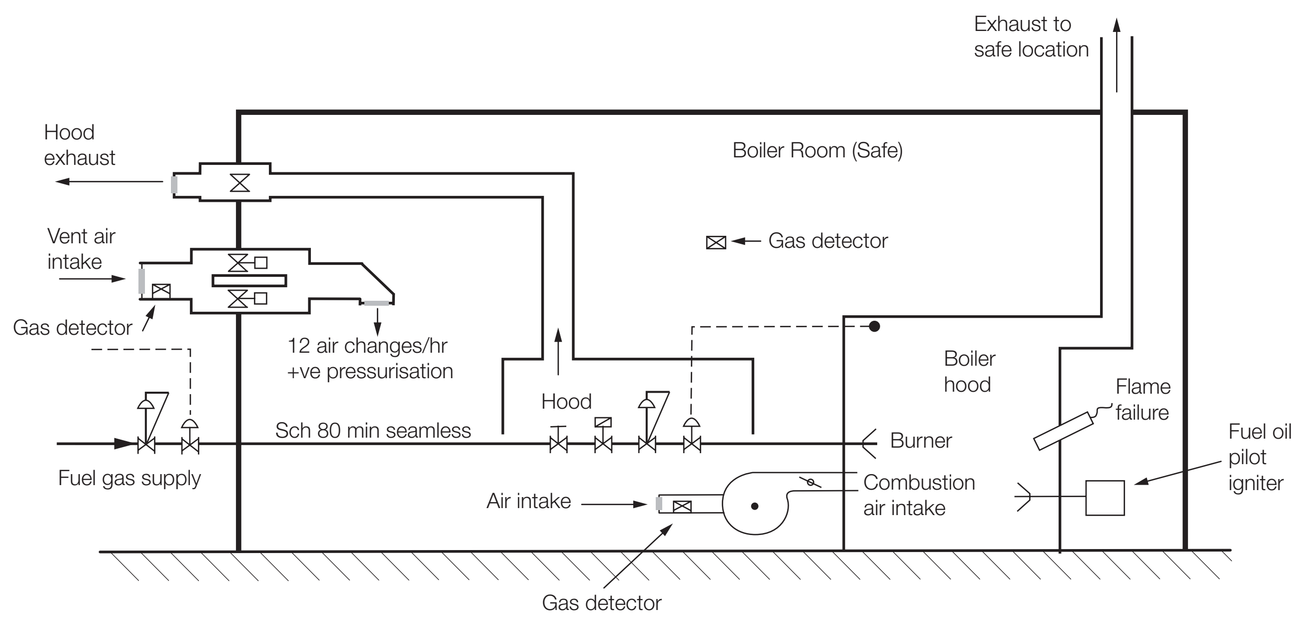

Fig. 14.3.1 Diagram showing the typical arrangements for a boiler room

Section 1 General

1.1 Application

1.1.1 Requirements for piping systems for oil storage tanks are given in Pt 5, Ch 15 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section 1
General requirements

1.1 General

1.1.1 Gas from the unit's process plant may be utilised as fuel in gas turbines/engines and auxiliary boilers/fired heaters, and crude oil/slops may be used in auxiliary boilers/fired heaters, provided the requirements of this Chapter are complied with. Diagrammatic plans showing ventilation arrangements, piping system layout and safety devices should be submitted for approval in each case.

1.1.2 Boilers, turbines, etc., which are arranged for burning gas or crude oil/slops are to be located within designated non-hazardous areas such as a boiler or turbine room or enclosure.

1.1.3 The design and construction of turbines, boilers, burners, etc., is to be suitable for operation on gas or crude oil as appropriate, effectively maintaining stable and complete combustion under all operating conditions.

1.1.4 The design of gas-burning internal combustion reciprocating engines and turbines will be specially considered in each case. For special requirements relating to boilers/fired heaters burning gas or crude oil/slops, *see* 1.6.

1.1.5 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Fuel gas supply arrangements

1.2.1 Gas which is taken directly from the process plant is to be treated before distribution. The system should include suitable treatment equipment to provide well-mixed, liquid-free gas at constant pressure.

1.2.2 The gas treatment system is to be located within a designated hazardous area. This area is to be separated from the boiler room or machinery space by a gas-tight bulkhead.

1.2.3 Liquid drains from the treatment equipment are to be led to a closed drain recovery system. Gas lines downstream of the treatment equipment should be heat traced or insulated as necessary to prevent condensation and hydrate formation.

1.2.4 A separate and independent gas supply line is to be provided for each gas burning unit and each line is to be provided with a fuel gas master valve arranged to close automatically if gas leakage is detected, or on loss of the required ventilation from the pipe duct or casing, or loss of pressurisation of the double-walled piping, *see* 1.4.2.

1.2.5 The fuel gas master valves and pressure regulators/reducing valves are to be located external to the boiler room or machinery space.

1.2.6 The gas supply line to each gas burning unit is to be fitted with a double block-and-bleed system utilising three automatic valves comprising two valves in series enabling the gas supply to be shut off and vented via a third valve to atmosphere at a safe location. These valves are to be arranged so that failure of the required ventilation, flame failure at the burners, abnormal gas supply pressure or loss of the valve actuating medium will cause the two valves in series to close and the vent valve between them to open. The valves are to be arranged for manual reset.

1.2.7 All master valves and block-and-bleed valves are to be arranged for remote operation from a location outside the boiler room or machinery space, and for local operation from the boiler or turbine control console.

1.2.8 The operation of the master valves or block-and-bleed valves is to activate an alarm in the machinery space and in the central control room.

1.2.9 For long runs of high pressure gas piping, consideration should be given to the fitting of a self-closing 'safety block valve' between adjoining all-welded sections of piping, which would automatically isolate the gas supply in cases of pipe fracture.

1.2.10 Provision is to be made for gas-freeing and inerting that portion of the fuel gas piping system located in the boiler room or machinery space.

1.2.11 Suitable arrangements are to be made for change over between gas and oil fuel so that change over can be accomplished quickly and easily.

1.3 Crude oil supply arrangements

1.3.1 Crude oil or slops may be taken directly from the unit's storage tanks, or from other suitable tanks. Such tanks are to be separated from non-hazardous areas by means of cofferdams with gas-tight bulkheads. Where crude oil/slops in tanks is preheated, its temperature is to be automatically controlled and a high temperature alarm and cut-out fitted.

1.3.2 The crude oil/slops transfer and treatment system (pumps, strainers, separators, etc.) is to be located within a designated hazardous area, such as a pump-room. This area is to be separated from the boiler room and other machinery spaces by gas-tight bulkheads.

1.3.3 Where crude oil/slops is heated by steam or hot water, the outlet from the heating coils is to be led to a separate, closed observation tank located within a designated hazardous area, together with the transfer and treatment components. This tank is to be fitted with a vent pipe led to atmosphere at a safe location, and the vent outlet fitted with a suitable flame arrester.

1.3.4 Pumps are to be fitted with a pressure relief valve in closed circuit discharging to the suction side, and are to be capable of being stopped from the machinery control room and from near the boiler front, as well as locally in the compartment in which they are situated.

1.3.5 Prime movers for pumps, etc., (excluding hydraulic motor drives) are to be located in a non-hazardous machinery space. Where drive shafts pass through a pump-room bulkhead or deck, gas-tight glands are to be fitted. These glands are to be effectively lubricated from outside the pump-room, *see also* Pt 5, Ch 15,3.2.4 of the *Rules and Regulations for the Classification of Ships*.

1.3.6 The crude oil piping is, as far as practicable, to be installed with an inclination rising towards the boiler so that the oil naturally returns towards the pumps in the case of leakage or failure in delivery pressure.

1.3.7 Crude oil delivery and return pipes are to be fitted with fail-close, shut-off master valves located external to the boiler room and remotely controlled from a position near the boiler fronts and from the machinery control room. These valves are to be arranged to close automatically on failure of duct ventilation or on detection of crude oil leakage within the duct.

1.3.8 The crude oil supply line to each burner unit is to be fitted with an automatic shut-down valve arranged so that failure of the forced draught fan, boiler hood exhaust fan, flame failure at the burner or loss of the valve actuating medium will cause the valve to close. The valves are to be arranged for local operation and for manual reset.

1.3.9 The operation of the master valves or burner shutdown valves is to activate an alarm in the boiler room and in the central control room.

1.3.10 Provision is to be made for gas-freeing and inerting that portion of the crude oil piping system located in the boiler room or machinery space.

1.3.11 Suitable arrangements are to be made for change over between crude oil/slops and oil fuel so that change over can be accomplished quickly and easily.

1.4 Piping requirements

1.4.1 Fuel gas and crude oil piping is to be entirely separate from other piping systems and is not to pass through accommodation, service spaces or control stations. Such piping within the boiler room or machinery space is to be enclosed in a ventilated, gas-tight duct or be doublewalled as per either 1.4.2 or 1.4.3 respectively. For piping external to the boiler room or machinery space, or passing through enclosed non-hazardous spaces, *see* 1.4.6.

1.4.2 The piping is to be installed within a ventilated, gas-tight duct, and this duct is to be connected to the bulkhead where it enters the boiler room or machinery space and to the burner unit(s) enclosure. The duct is to be provided with mechanical ventilation having a capacity of at least 30 air changes per hour and arranged to maintain a pressure less than atmospheric pressure. The ventilation outlet is to be located at a safe location where no gas-air mixture could be ignited. The duct ventilation is to be in continuous operation when fuel is in the piping. Continuous gas monitoring is to be provided in the duct to detect leaks, and arranged to automatically close the master valve in accordance with 1.2.4 or 1.3.7.

1.4.3 Alternatively, the piping may be a double-walled piping system with the fuel contained in the inner pipe and the annular space between pipes pressurised with inert gas to a pressure greater than the fuel pressure. Alarms are to be provided to indicate loss of pressure between the pipes and the master valves arranged to automatically close in accordance with 1.2.4 or 1.3.7.

1.4.4 Piping connections are to be reduced to the minimum required for installation and machinery maintenance. All piping is to be suitably and adequately supported so as to avoid vibration.

1.4.5 The piping for conveying fuel gas or crude oil/slops, and for the drainage pipes from the tray specified in 1.6.3, is to have a minimum wall thickness as specified for oil fuel systems in Chapter 12.

1.4.6 Gas and crude oil/slops supply and return pipes which are located external to the boiler room or machinery space in open or semi-enclosed non-hazardous areas are to be of seamless heavy gauge steel with a minimum wall thickness of Sch 80, and have fully radiographed, full penetration, butt welded joints. Pipe connections are to be of the heavy flange type. This piping is to be clearly identifiable by means of a suitable colour code. Piping passing through enclosed non-hazardous spaces will be specially considered.

1.5 Boiler room and machinery space ventilation

1.5.1 Ventilation of the boiler rooms and machinery spaces is to be at a pressure above atmospheric pressure by a separate ventilation system independent of all other ventilation systems, and providing at least 12 air changes per hour. At least two 100 per cent capacity fans are to be fitted. If the boiler, turbine, etc., is installed in a confined part of the boiler room or machinery space, the ventilation requirements apply to that part of the space only. For particular requirements relating to gas turbine ventilation, *see* Pt 7, Ch 2,6.5.

1.5.2 The ventilation system is to ensure good air circulation in all spaces, and in particular to prevent the formation of stagnant pockets of gas within the space. Gas detectors are to be fitted at appropriate locations in these spaces, particularly where air circulation may be restricted.

1.5.3 Where released gases are likely to be heavier than air as in the case of crude oil systems, extraction ducts should be located at a low level within the boiler room. Open mesh floor plates should be utilised as required to ensure efficient extraction of gases.

1.5.4 The ventilation air intakes are to be from an external non-hazardous area, at least 3 m from the boundary of any hazardous area. Ventilation outlets are to be led to atmosphere at a safe location.

1.5.5 Boilers and turbines are to be fitted with a suitable hood or casing, arranged so as to enclose as much as possible of the burners and associated valves and pipes, but without restricting the air flow to the burner registers. The hood or casing should be installed to ensure that the ventilating air sweeps across the enclosed valves, etc., and be fitted with doors as necessary for inspection of, and access to, the burner units, valves and pipes.

1.5.6 The boiler/turbine hood is to be fitted with a ventilation duct led to atmosphere at a safe location, and with the vent outlet fitted with a suitable flame-proof wire gauze. At least two 100 per cent capacity extraction fans with spark-proof impellers are to be fitted to maintain the pressure inside the hood less than that of the boiler room or machinery space. The fans are to be arranged for automatic change over to the standby fan on failure of the operational fan. The fan prime movers are to be placed outside the duct with gas-tight drive shaft penetration through the duct casing.

1.5.7 Means of continuous gas detection is to be provided in way of the hood and gas pipe ducting and arranged to provide an audible and visual alarm at 30 per cent lower explosive limit and shut-down of the fuel supply before the gas concentration reaches 60 per cent of the lower explosive limit.

1.6 Special requirements for boilers/fired heaters

1.6.1 The arrangement of boilers and burner systems is to comply, in general, with the requirements of Chapter 14, as applicable. The whole of the boiler casing is to be gas-tight and each boiler is to have a separate uptake.

1.6.2 The arrangement of burner units and all associated valves is to be such that the fuel gas or crude oil/slops is ignited by the flame of the oil fuel burner. A flame scanner is to be installed and arranged to ensure that the fuel supply to the burner is cut off unless satisfactory ignition has been established and maintained. A manually operated shut-off valve and flame arrester is to be fitted to each burner unit.

1.6.3 Boilers for burning crude oil/slops are to be fitted with a tray or gutterway of suitable height placed in such a way so as to collect any possible oil leakage from burners, valves or connections. The tray or gutterway is to be fitted with a drain pipe discharging into a separate, closed collecting tank in the boiler room, pump-room or other suitable location. This tank is to be fitted with a vent pipe led to atmosphere at a safe location, and with the vent outlet fitted with a suitable flame arrester, and with provision for drainage to a suitable tank outside the machinery space.

1.6.4 Means are to be provided for the boiler to be automatically purged before firing or relighting. Arrangements are also to be provided to allow manual purging, but interlocking devices should be fitted to ensure that purging can only be carried out when the burner fuel supply valves are closed.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for fusion welding of pressure vessels and piping are given in Pt 5, Ch 17 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for integrated propulsion systems are given in Pt 5, Ch 18 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1 General

1.1 Application

1.1.1 Requirements for steering gear applicable to units designed to undertake self-propelled passages without external assistance are given in Pt 5, Ch 19 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which should be complied with in addition to the requirements in this Section.

1.1.2 When a ship unit is classed as a floating offshore installation at a fixed location and the rudder is inoperative, *see* Pt 4, Ch 10,1.

1.1.3 Where rudders are left *in situ* on ship units, positive locking devices are to be fitted to steering gears to prevent rudders moving violently in storm conditions. Plans, together with supporting design calculations, are to be submitted for approval to show satisfactory capacity in the worst contemplated environmental conditions.

1.1.4 Consideration of the predicted extreme wind and wave loadings, unit orientation and wave headings, together with all other relevant environmental conditions at the operating site, are to be taken into account in predicting forces and moments on the rudder control systems.

1.1.5 In some circumstances, the positive locking devices required by 1.1.3 may be omitted if it can be shown that, during storm conditions, the existing (installed) hydraulic steering control system, either temporarily power-operated or left with passive trapped hydraulic fluid in the circuit but with relief valves open, is sufficient to counteract or dampen the imposed rudder moments such as to control violent movements of the rudder. However, in such cases, it may still prove necessary to carry out fatigue analysis of the rudder to tiller and support arrangements, taking into account the expected environmental sea wave velocity spectrums and structural natural frequencies to ensure satisfactory fatigue lives.

1.1.6 With reference to Pt 5, Ch 19,5.1.6, 5.2.2(a) and 6.1.1 of the Rules for Ships, *see also* Pt 6, Ch 2,3.7.9.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g., tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the unit under normal service conditions.

1.2.3 **Steering gear power unit** means:
(a) in the case of electric steering gear, an electric motor and its associated electrical equipment;
(b) in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;
(c) in the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary to steer the unit in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e., tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the unit is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which convert directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with 2.1.2(b).

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be:

(a) readily accessible and, as far as practicable, separated from machinery spaces; and

(b) Provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

1.4 Plans

1.4.1 Before starting construction, the steering gear machinery plans, specifications and calculations are to be submitted. The plans are to give:

(a) Details of scantlings and materials of all load bearing and torque transmitting components and hydraulic pressure-retaining parts together with proposed rated torque and all relief valve settings.

(b) Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.

(c) Details of control and electrical aspects.

1.5 Materials

1.5.1 All the steering gear components and the rudder stock are to be of sound reliable construction to the Surveyor's satisfaction.

1.5.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5.3 Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings, and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material, duly tested in accordance with the requirements of the Rules for Materials. In general, such material is to have an elongation of not less than 12 per cent and a tensile strength not in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

1.5.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

1.6 Rudder, rudder stock, tiller and quadrant

1.6.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 13,2 of the Rules for Ships.

1.6.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see* Table 19.1.1.

1.6.3 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

1.6.4 The factor of safety against slippage, S (i.e., for torque transmission by friction) is generally based on:

$$S = \frac{\text{the torque transmissible by friction}}{M}$$

where

M is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

1.6.5 For conical sections, S is based on the following equation:

$$S = \frac{\mu\, A\, \sigma_r}{\sqrt{(W + A\, \sigma_r\, \theta)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2

W = weight of rudder and stock, if applicable, when tending to separate the fit, in N

Q = shear force = $\dfrac{2M}{d_m}$ in N

where

d_m is the mean contact diameter of tiller/stock interface and M in Nmm is defined in 1.6.4, in mm

θ = cone taper half angle in radians (e.g., for cone taper 1:10, θ = 0,05)

μ = coefficient of friction

σ_r = radial interfacial pressure or grip stress, in N/mm^2.

Table 19.1.1 Connection of tiller to stock

Item	Requirements
(1) Dry fit – tiller to stock, *see also* 1.6.4 and 1.6.5	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent Von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock, *see also* 1.6.4 and 1.6.5	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent Von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit – tiller to stock, *see also* 1.6.3	(a) Factor of safety against slippage, S = 2,0 The maximum equivalent Von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2
(4) Bolted tiller and quadrant (this arrangement could be accepted provided the proposed rudder stock diameter in way of tiller does not exceed 350 mm diameter), *see* symbols	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: $t_s = 0{,}0014\ \delta_t$ mm For 6 connecting bolts: $t_s = 0{,}0012\ \delta_t$ mm Key(s) to be fitted Diameter of bolts, $\delta_{tb} = \dfrac{0{,}60\ \delta_{su}}{\sqrt{n_{tb}}}$ mm A predetermined setting-up load equivalent to a stress of approximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted Distance from centre of stock to centre of bolts should generally be equal to $\delta_t \left(1{,}0 + \dfrac{0{,}30}{\sqrt{n_{tb}}}\right)$ mm Thickness of flange on each half of the bolted tiller ≥ $\dfrac{0{,}66\ \delta_t}{\sqrt{n_{tb}}}$ mm
(5) Key/keyway, *see* symbols	Effective sectional area of key in shear ≥ $0{,}25\ \delta_t^2$ mm^2 Key thickness ≥ $0{,}17\ \delta_t$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress
(6) Section modulus – tiller arm (at any point within its length about vertical axis), *see* symbols	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15\ \delta_t^3\ (b_T - b_s)}{1000\ b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06\ \delta_t^3\ (b_T - 0{,}9\ \delta_t)}{1000\ b_T}$ cm^3 If more than one arm fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 2
(7) Boss, *see* symbols	Depth of boss ≥ δ_t Thickness of boss in way of tiller ≥ $0{,}4\ \delta_t$

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm

n_{tb} = number of bolts in the connection flanges, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

δ_t = Rule rudderstock diameter in way of tiller, *see* Pt 3, Ch 13 of the Rules for Ships

δ_{tb} = diameter of bolts securing bolted tillers and quadrants, in mm

Section 2 **Performance**

2.1 General

2.1.1 Unless the main steering gear comprises two or more identical power units, in accordance with 2.1.4 or 8.1.1, every unit is to be provided with a main steering gear and an auxiliary steering gear, in accordance with the requirements of the Rules. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

2.1.2 The main steering gear and rudder stock is to be:
(a) Of adequate strength and capable of steering the unit at maximum ahead service speed, which shall be demonstrated in accordance with 7.2;
(b) Capable of putting the rudder over from 35° on one side to 35° on the other side with the unit at its deepest sea-going draught and running ahead at maximum ahead service speed and under the same conditions, from 35° on either side to 30° on the other side in not more than 28 seconds;
(c) Operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 120 mm diameter in way of the tiller; and
(d) So designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

2.1.3 The auxiliary steering gear is to be:
(a) Of adequate strength and capable of steering the unit at navigable speed and of being brought speedily into action in an emergency;
(b) Capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds with the unit at its deepest sea-going draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
(c) Operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 230 mm diameter in way of the tiller.

2.1.4 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted, provided that the main steering gear is arranged so that, after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

2.1.5 Main and auxiliary steering gear power units are to be:
(a) Arranged to restart automatically when power is restored after power failure;
(b) Capable of being brought into operation from a position on the navigating bridge. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given on the navigating bridge;
(c) Arranged so that transfer between units can be readily effected.

2.1.6 Where the steering gear is so arranged that more than one power or control system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

2.1.7 A means of communication is to be provided between the navigating bridge and the steering gear compartment.

2.1.8 Steering gear, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

2.2 Rudder angle limiters

2.2.1 Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear only and not with the steering gear control.

Section 3 **Construction and design**

3.1 General

3.1.1 Rudder actuators other than those covered by 8.3 and the ‘Guidelines’ are to be designed in accordance with the relevant requirements of Chapter 11 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

3.1.2 Accumulators, if fitted, are to comply with the relevant requirements of Chapter 11.

3.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

3.1.4 The construction is to be such as to minimise local concentrations of stress.

3.1.5 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure, which is to be expected under the operational conditions specified in 2.1.2(b), taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads, *see* Section 9.

3.1.6 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material at ambient temperature

A and *B* are given by the following Table:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	3,5	4	5
B	1,7	2	3

3.2 Components

3.2.1 Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilise anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

3.2.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength of at least the equivalent to that of the rudder stock in way of the tiller.

3.2.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal type or of an equivalent type.

3.2.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

3.2.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Chapter 12 for Class I piping systems components. The design pressure is to be in accordance with 3.1.5.

3.2.6 Hydraulic power-operated steering gears are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power-operated. The storage tank is to be permanently connected by piping, in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a contents gauge.

3.3 Valve and relief valve arrangements

3.3.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

3.3.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

3.3.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and where pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

3.3.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 3.3.3, are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.

(b) the minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can be delivered through them. Under such conditions, the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions, in respect of oil viscosity.

3.4 Flexible hoses

3.4.1 Hose assemblies approved by LR may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery, *see also* Ch 12,7.

3.4.2 Hoses should be high pressure hydraulic hoses, according to recognised standards and should be suitable for the fluids, pressures, temperatures and ambient conditions in question.

3.4.3 Burst pressure of hoses is to be not less than four times the design pressure.

■ *Section 4* Steering control systems

4.1 General

4.1.1 Steering gear control is to be provided:

(a) For the main steering gear, both on the navigating bridge and in the steering gear compartment;
(b) Where the main steering gear is arranged according to 2.1.4, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system does not need to be fitted, except in a oil storage unit of 10000 gross tonnage and upwards;
(c) For the auxiliary steering gear, in the steering gear compartment and, if power-operated, it shall also be operable from the navigating bridge and is to be independent of the control system for the main steering gear; and
(d) Where the steering gear is so arranged that more than one control system can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

4.1.2 Any main and auxiliary steering gear control system, operable from the navigating bridge, is to comply with the following:

(a) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves;
(b) The system is to be capable of being brought into operation from a position on the navigating bridge.

4.1.3 The angular position of the rudder shall:

(a) Be indicated on the navigating bridge, if the main steering gear is power-operated. The rudder angle indication is to be independent of the steering gear control system;
(b) Be recognisable in the steering gear compartment.

4.1.4 Appropriate operating instructions with a block diagram showing the changeover procedures for steering gear control systems and steering gear actuating systems, which are to be permanently displayed in the wheelhouse and in the steering gear compartment.

4.1.5 Where the system failure alarms for hydraulic lock, *see* Table 19.5.1, are provided, appropriate instructions shall be placed on the navigating bridge to shut down the system at fault.

■ *Section 5* Electric power circuits, electric control circuits, monitoring and alarms

5.1 Electric power circuits

5.1.1 Short-circuit protection, an overload alarm and, in the case of polyphase circuits, an alarm to indicate single phasing is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or be circuit protected. They are to allow excess current to pass during the normal accelerating period of the motors.

5.1.2 The alarms required by 5.1.1 are to be provided on the bridge and in the main machinery space or control room from where the main machinery is normally controlled.

5.1.3 Indicators for running indication of each main and auxiliary motor are to be installed on the navigating bridge and at a suitable main machinery control position.

5.1.4 A low-level alarm is to be provided for each power actuating system and hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

5.1.5 Two exclusive circuits are to be provided for each electric or electrohydraulic steering gear arrangement, consisting of one or more electric motors.

5.1.6 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard. *See also* Pt 6, Ch 2,3.7.9.

5.1.7 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

5.1.8 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and that can operate simultaneously.

5.1.9 These circuits are to be permanently separated and as widely as is practicable.

5.1.10 In units of less than 1600 gross tonnage, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than what is described in 5.1.1, for such a motor which is primarily intended for other services.

5.2 Electric control circuits

5.2.1 Electric control systems are to be independent and separated as far as is practicable throughout their length.

5.2.2 Each main and auxiliary electric control system which is to be operated from the navigating bridge is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected. *See also* Pt 6, Ch 2,3.7.9.

(b) Each separate circuit is to be provided with short-circuit protection only.

5.3 Monitoring and alarms

5.3.1 Alarms and monitoring requirements are indicated in 5.3.2 and Table 19.5.1.

Table 19.5.1 Alarm requirements

Item	Alarm	Note
Rudder position	— Failure	Indication, *see* 4.1.3 *See* 5.3.3
Steering gear power units, power	Failure	—
Steering gear motors	Overload Single phase	For alarm and running indication locations, *see* 5.1.2 and 5.1.3
Control system	Failure	*See* 5.3.3
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be monitored. For alarm locations, *see* 5.1.4
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and to be activated when (for example):

- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

5.3.2 The alarms described in Table 19.5.1 are to be indicated on the navigating bridge and additional locations are to be described in accordance with the alarm system, as specified by Pt 6, Ch 1,2.3.

5.3.3 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and feedback circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

■ *Section 6* Emergency power

6.1 General

6.1.1 Where the rudder stock is required to be over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply, sufficient at least to supply the steering gear power unit, which complies with the requirements of 2.1.3 and also its associated control system and the rudder angle indicator, shall be provided automatically, within 45 seconds, either from the emergency source of electrical power, *see also* Pt 6, Ch 2,3.7.9, or from an independent source of power located in the steering gear compartment. This independent source of power should only be used for this purpose.

6.1.2 In every unit of 10 000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 minutes of continuous operation and in any other unit for at least 10 minutes.

6.1.3 Where the alternative power source is a generator, or an engine driven pump, starting arrangements are to comply with the requirements relating to the starting arrangements of emergency generators.

■ *Section 7* Testing and trials

7.1 Testing

7.1.1 The requirements of the Rules relating to the testing of Class 1 pressure vessels, piping, and related fittings, including hydraulic testing apply.

7.1.2 After installation on board the unit, the steering gear is to be subjected to the required hydrostatic and running tests.

7.1.3 Each type of power unit pump is to be subjected to a type test. The type test shall be for a duration of not less than 100 hours and the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test, no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

7.2 Trials

7.2.1 The steering gear is to be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering gear, including demonstration of the performances required by 2.1.2(b) and 2.1.3(b):
- For the main steering gear trial, the propeller pitch of controllable pitch propellers is to be at the maximum design pitch approved for the maximum continuous ahead RPM;
- If the unit cannot be tested at the deepest draught, alternative trial conditions may be specially considered. In this case, for the main steering gear trial, the speed of the ship unit corresponding to the maximum continuous revolutions of the main engine should apply:

(b) The steering gear power units, including transfer between steering gear power units;
(c) The isolation of one power actuating system, checking the time for regaining steering capability;
(d) The hydraulic fluid recharging system;
(e) The emergency power supply required by 6.1.1;
(f) The steering gear controls, including transfer of control and local control;
(g) The means of communication between the steering gear compartment and the wheelhouse, also the engine room, if applicable;
(h) The alarms and indicators;
(j) Where the steering gear is designed to avoid hydraulic locking, this feature shall be demonstrated.

Test items (d), (g), (h) and (j) may be effected at the dockside.

■ *Section 8* Additional requirements

8.1 For oil storage units of 10 000 tons gross and upwards and every other unit of 70 000 tons gross and upwards

8.1.1 The main steering gear is to comprise of two or more identical power units, complying with provisions of 2.1.4.

8.2 For oil storage units of 10 000 tons gross and upwards

8.2.1 Subject to 8.3, the following are to be complied with:

(a) The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained in no more than 45 seconds after the loss of one power actuating system.

(b) The main steering gear is to comprise of either:
  (i) two independent and separate power actuating systems, each capable of meeting the requirements of 2.1.2(b); or
  (ii) at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of 2.1.2(b). Where necessary to comply with these requirements, inter-connection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system is automatically isolated so that the other actuating system or systems remain fully operational.

(c) Steering gears other than the hydraulic type are to achieve equivalent Standards.

8.3 For oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

8.3.1 Solutions other than those set out in 8.2.1, which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety Standard is achieved and that:

(a) Following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is regained within 45 seconds; and

(b) Where the steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design, including fatigue analysis and fracture mechanics analysis, as appropriate, the material used, the installation of sealing arrangements and the testing and inspection and provision of effective maintenance. In consideration of the foregoing arrangements, regard will be given to the 'Guidelines' in Section 9.

8.3.2 Manufacturers of the steering gear who intend their product to comply with the requirements of the 'Guidelines', are to submit full details when plans are forwarded for approval.

■ Section 9
'Guidelines' for the acceptance of non-duplicated rudder actuators for oil storage units of 10 000 tons gross and upwards but of less than 100 000 tons deadweight

9.1 Materials

9.1.1 Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder stock are to be made of duly tested ductile materials complying with recognised Standards. Materials for pressure retaining components are to be in accordance with recognised pressure vessel Standards. These materials are not to have an elongation less than 12 per cent, nor a tensile strength in excess of 650 N/mm^2.

9.2 Design

9.2.1 **Design pressure**. The design pressure should be assumed to be at least equal to the greater of the following:

(a) 1,25 times the maximum working pressure to be expected under the operating conditions required in 2.1.2(b).

(b) The relief valve(s) setting.

9.2.2 **Analysis**. In order to analyse the design, the following are required:

(a) The manufacturers of rudder actuators should submit detailed calculations showing the suitability of the design for the intended service.

(b) A detailed stress analysis of pressure retaining parts of the actuator should be carried out to determine the stresses at the design pressure.

(c) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all foreseen dynamic loads should be taken into account. Experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations depending upon the complexity of the design.

9.2.3 **Dynamic loads for fatigue and fracture mechanics analysis**. The assumption for dynamic loading for fatigue and fracture mechanics analysis where required by 3.1.5, 8.3 and 9.2.2 are to be submitted for appraisal. Both the case of high cycle and cumulative fatigue are to be considered.

9.2.4 **Allowable stresses**. For the purposes of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses should not exceed:

$$\sigma_m \leq f$$
$$\sigma_1 \leq 1{,}5f$$
$$\sigma_b \leq 1{,}5f$$
$$\sigma_1 + \sigma_b \leq 1{,}5f$$
$$\sigma_m + \sigma_b \leq 1{,}5f$$

where

f = the lesser of $\dfrac{\sigma_B}{A}$ or $\dfrac{\sigma_y}{B}$

σ_b = equivalent primary bending stress

σ_m = equivalent primary general membrane stress

σ_y = specified minimum yield stress or 0,2 per cent proof stress of material at ambient temperature

σ_B = specified minimum tensile strength of material at ambient temperature

σ_1 = equivalent primary local membrane stress

A and *B* are as follows:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	4	4,6	5,8
B	2	2,3	3,5

9.2.5 **Burst test**. Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required by 9.2.2 need not be provided.

The minimum bursting pressure should be calculated as follows:

$$P_b = P A \frac{\sigma_{Ba}}{\sigma_B}$$

where

A = as from Table in 9.2.4

P = design pressure, as defined in 9.2.1

P_b = minimum bursting pressure

σ_B = tensile strength, as defined in 9.2.4

σ_{Ba} = actual tensile strength.

9.3 Construction details

9.3.1 **General**. The construction should be such as to minimise local concentrations of stress.

9.3.2 **Welds**.

(a) The welding details and welding procedures should be approved.

(b) All welded joints within the pressure boundary of a rudder actuator or connection parts transmitting mechanical loads should be a full penetration type or of equivalent strength.

9.3.3 **Oil seals**. Oil seals forming part of the external pressure boundary are to comply with 3.2.3 and 3.2.4.

9.3.4 **Isolating valves** are to be fitted at the connection of pipes to the actuator, and should be directly mounted on the actuator.

9.3.5 **Relief valves** for protecting the rudder actuator against over-pressure as required in 3.3.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure expected under operating conditions required by 2.1.2(b).

(b) The minimum discharge capacity of the relief valve(s) is to be not less than 110 per cent of the total capacity of all pumps which provided power for the actuator. Under such conditions, the rise in pressure should not exceed 10 per cent of the setting pressure. In this regard, due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

9.4 Non-destructive testing

9.4.1 The rudder actuator should be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for non-destructive testing should be in accordance with requirements of recognised Standards. If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

9.5 Testing

9.5.1 Tests, including hydrostatic tests, of all pressure parts at 1,5 times the design pressure should be carried out, subject to any limitations imposed by valves and other components. Where additional testing of systems or subsystems following final assembly is required, the test pressure may be subject to any limitations imposed by valves and other components.

9.5.2 When installed on board the unit, the rudder actuator should be subjected to a hydrostatic test at the pressure, defined in 9.5.1, as well as a running test.

9.6 Additional requirements for steering gear fitted to units with Ice Class notations

9.6.1 *See* Pt 3, Ch 6.

Section

Section 1 General

1.1 Application

1.1.1 Requirements for azimuth thrusters are given in Pt 5, Ch 20 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for condition monitoring systems are given in Pt 5, Ch 21 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

Section

Section 1
General

1.1 Application

1.1.1 Requirements for the redundancy of propulsion and steering machinery are given in Pt 5, Ch 22 of the *Rules and Regulations for the Classification of Ships*, which should be complied with.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to self-elevating units with machinery of the rack and pinion type used to raise and lower the position of the hull with respect to the legs, or other supporting structure above the surface of the sea.

1.1.2 Machinery for self-elevating units utilising other systems will be specially considered.

1.2 Definitions

1.2.1 The following definitions are applicable to this Chapter:

(a) **Normal jacking load**. The maximum design elevated weight of the hull, including variable load, to be raised/ lowered by the jacking unit, during normal jacking operation.
(b) **Pre-load jacking load**. The maximum design elevated weight of the hull, including pre-load ballast load, to be lowered by the jacking unit in the event of sudden leg penetration during pre-load operation.
(c) **Pre-load holding load**. The maximum design elevated weight of the hull, including pre-load ballast, to be held by the jacking unit during the pre-load operation.
(d) **Ultimate holding load**. The maximum load capable of being held by the jacking unit, in an emergency situation, without causing slippage of the jacking gear machinery braking device.
(e) **Storm survival load**. The maximum static design load in the leg to be supported by the jacking and/or fixation systems.
(f) **Fixation system**. The mechanical locking device, with an engaging mechanism, used to provide positive engagement between the hull support structure and the leg chord.
(g) **Jacking gear unit**. The individual reduction gear assembly, comprising drive motor, coupling, enclosed reduction gearing and main pinion normally attached to the jack-house.
(h) **Jack-house**. The structure surrounding the leg chord into which multiple jacking units are installed.

1.3 Submission of plans and particulars

1.3.1 The following plans, together with the necessary particulars of the jacking mechanism are to be submitted for consideration:

- General arrangement of the self-elevating machinery, including a cross-sectional arrangement.
- Full design details of all transmission gear elements including gear tooth geometry and machining details.
- Full design details of all transmission shafting, couplings, coupling bolts, interference assemblies, keys, keyways.
- Bearing details.
- Enclosed gear casing details and mounting arrangements.
- All assembly design tolerances are to be submitted, including, where applicable, allowances for wear during normal operation such as rack guides.
- Prime mover specifications including braking devices.
- Drawing of main pinion and rack tooth profile showing full geometric details.
- Full design details of the fixation system, where fitted.
- A load-time spectrum for the envisaged dynamic operational requirements of the self-elevating machinery for the unit is to be specified.
- A simulated load analysis for the main pinion/rack tooth mesh during wet/dry tow conditions.

1.4 Material specifications

1.4.1 Specifications for materials for the gearing and other mechanical components giving chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans required by 1.3.1.

1.4.2 Where the teeth of a pinion or gear wheel are to be surface-hardened (i.e., carburised, nitrided, tufftrided or induction-hardened) the proposed specification and details of the procedure are to be submitted for approval.

■ *Section 2* Materials

2.1 Material properties

2.1.1 Materials used for the construction of the jacking gear machinery are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or a National Standard acceptable to LR. *See* Ch 1,2.2 of the Rules for Materials for additional requirements for materials.

2.2 Non-destructive tests

2.2.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

2.2.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth. This examination may also be requested on the finished machined teeth of through-hardened gears.

Section 3 Design

3.1 General

3.1.1 Self-elevating systems are to be designed with redundancy such that a single failure of any component will not cause an uncontrolled descent of the unit or impair the safety of the unit. Each leg is to be provided with a load indication and an overload alarm at a manned control station.

3.1.2 Braking devices are to fail safe in the engaged position in the event of a failure or interruption of the power supply to the lifting machinery.

3.1.3 Unless otherwise agreed by LR, the system is to be designed such that the rack tooth is the weakest component in the self-elevating machinery with regard to static mechanical strength.

3.1.4 The jacking system, together with the fixation system if fitted, is to be capable of adequately lifting and supporting the hull, or leg installation under all operating, survival and tow conditions.

3.1.5 The self-elevating mechanism is to be designed to pre-load the foundation to the design conditions and be capable of supporting a load not less than the maximum load for which the leg has been designed.

3.1.6 The requirement for emergency jacking of the hull with full or part pre-load to stabilise the unit in the event of sudden leg penetration is to be considered.

3.1.7 In selecting the prime movers for the self-elevating machinery, consideration is to be given to the effects of friction at the mesh of the pinion and rack, and between legs and guides, together with uneven load distribution.

3.1.8 Unless otherwise agreed, the minimum design operating temperature of the jacking gear machinery is to be in accordance with Pt 3, Ch 1,4.4.

3.1.9 The control station from which the elevating and lowering machinery is operated is to be provided with all necessary monitoring, alarms and controls including hull alignment, prime mover running load pin position, running indication, overload alarms and indication of availability of applicable power sources, as appropriate.

3.2 Enclosed gearing

3.2.1 All enclosed transmission gearing is to be designed in accordance with a National Standard acceptable to LR.

3.2.2 The design is to have sufficient load capacity to meet the minimum requirements of Tables 23.3.1 and 23.3.2 and 3.2.3 to 3.2.5.

Table 23.3.1 Tooth flank bending strength

Tooth root bending strength	Required factor of safety S_{Fmin}
Dynamic operation:	
Normal jacking of hull and legs	1,5
Pre-load jacking of hull (*see* Note 1)	1,5
Static operation:	
Normal holding load (without fixation system engaged) (*see* Note 2)	1,5
Pre-load holding	1,5
Symbols	
S_{Fmin} is defined as $\frac{\sigma_{FP}}{\sigma_F}$ σ_{FP} = allowable tooth root bending stress σ_F = calculated tooth root bending stress	
NOTES 1. Based on 50 hours operation. 2. It is considered that where a fixation system is properly engaged the loading applied to the jacking gears will be minimal.	

Table 23.3.2 Tooth flank Hertzian stress

Tooth flank Hertzian stress	Required factor of safety S_{Hmin}
Dynamic operation	1,0
Static operation	1,0
Symbols	
S_{Hmin} is defined as $\frac{\sigma_{FP}}{\sigma_F}$ σ_{FP} = allowable Hertzian bending stress σ_F = calculated Hertzian bending stress	

3.2.3 The following design values are to be used in the assessment of the gear design unless otherwise agreed:

- Application factor, K_A:
  Electric motor drive 1,0
- Load Sharing Factor $K\gamma$:
  With pinion load monitoring 1,0
  Without pinion load monitoring 1,2.

3.2.4 Material endurance strength limits are to comply with the requirements of a National Standard acceptable to LR.

3.2.5 Consideration is to be given to the loads applied to the gears during wet/dry tow conditions, as the gear teeth may be subjected to full load reversal. The design will be given consideration based on the simulated load analysis for the main pinion/rack tooth mesh.

3.3 Main pinion and rack

3.3.1 The design of the final (main) pinion and rack is subject to special consideration but the requirements of 3.3.2 to 3.3.7 are to be complied with.

3.3.2 The nominal contact ratio of the mesh is not to be less than 1,05, taking into consideration the cumulative effects of the design and assembly tolerance values and allowable wear during operation of the guides/rack tips.

3.3.3 The material hardness of the pinion is to be not less than that of the rack tooth material.

3.3.4 The pinion is to have a factor of safety on tooth root bending of not less than 1,5 for both static and dynamic loading conditions.

3.3.5 Hertzian tooth flank contact stress is generally not to be greater than three times the yield strength of the rack material, or not greater than 3,5 times the yield for pre-load jacking.

3.3.6 The ultimate strength (collapse load) of the main pinion tooth is not to be less than 1,1 times that of the rack tooth.

3.3.7 Consideration is to be given to the loads being applied to the main pinion mesh during wet/dry tow conditions where full load reversal may be expected.

3.4 Shafting

3.4.1 Nominal shaft stresses for the plain section solid shafting are to be calculated as follows:

$$\sigma_b = \frac{32\,000M}{\pi\, d_o^3}$$

$$\tau = \frac{16\,000T}{\pi\, d_o^3}$$

where

τ = calculated torsional shaft stress, in N/mm^2

T = shaft torque, in Nm

d_o = shaft outside diameter, in mm

σ_b = calculated bending shaft stress, in N/mm^2

M = bending moment, in Nm.

3.4.2 The maximum stresses due to bending and torsion are not to exceed the values shown in Fig. 23.3.1. The assessment of the maximum stresses should take into account the system overload conditions. The allowable stress limits in Fig. 23.3.1 include an allowance for stress concentrations at keyways, fillets shrink assemblies or other areas of stress concentration, not exceeding 3,0. Where an effective stress concentration exceeds this value, the design will be specially considered.

3.4.3 When designing a shaft for a finite number of rotating cycles, the allowable stresses may be increased by the factors in Table 23.3.3.

Table 23.3.3 Shaft stress multipliers

Cycles	Factor
Up to 1000 cycles	2,4
Over 1000 to 10 000 cycles	1,8
Over 10 000 to 100 000 cycles	1,4
Over 100 000 to 1 million cycles	1,1
1 million cycles and over	1,0

3.4.4 Shaft materials having properties outside the range covered by Fig. 23.3.1 will be specially considered.

3.5 Interference assemblies

3.5.1 A minimum factor of safety on slippage of 2,0 is to be achieved based on the maximum load.

3.6 Bearings

3.6.1 The capacity of the sleeve or anti-friction shaft bearings is to be such as to carry adequately the radial and thrust loads which would be induced under all operating conditions.

3.6.2 Hydrodynamic radial bearings are to be lined with babbitt or other material suitable for the intended application and duty. They are to be properly installed and secured in the housing against axial and rotational movement.

3.6.3 Selection of the particular design of sleeve bearing is to be based on an evaluation of the journal velocity, surface loading, hydrodynamic film thickness, and calculated bearing temperature under all operating conditions.

3.6.4 Selection of rolling element bearings is to be based upon the bearing manufacturer's recommendations for the design loading and application.

3.7 Braking device

3.7.1 Braking devices are to have a combined static friction torque capacity, considering the mechanical efficiency of the drive gear, such that no fewer than 1,3 times the maximum design load, to be supported during normal operation, may be held without brake slippage.

3.7.2 Means are to be provided such that, in the event of failure of one or more of the self-elevating machinery units, the defective unit(s) can be mechanically isolated such that the effectiveness of the remaining units in raising/lowering the hull is not impaired.

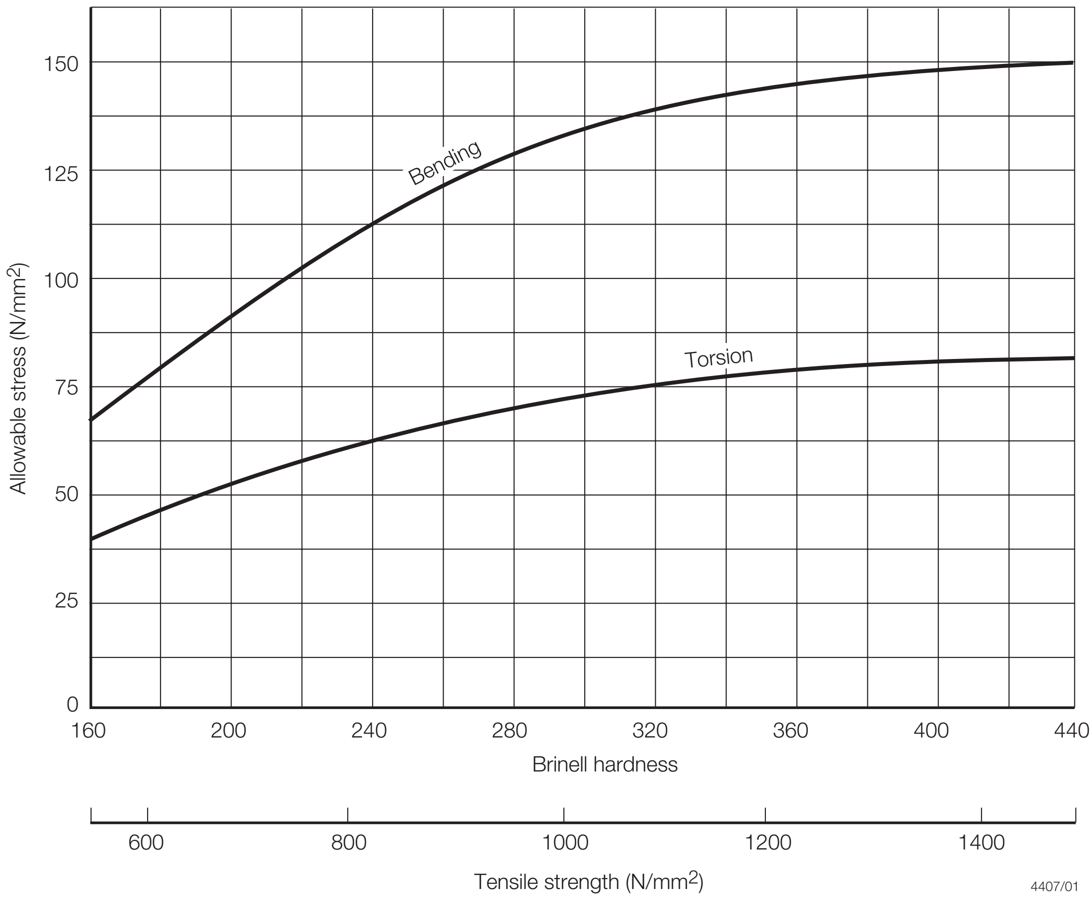

Fig. 23.3.1 Allowable stress – Shafting

3.8 Gear-case

3.8.1 The design of the attachment of the enclosed gearing gear-case to the jack-house or other supporting structure is to be such that the load reversals, where applicable, during jacking up and jacking down may be accommodated without relative movement between the gear-case and the jack-house.

3.9 Rack fixation system

3.9.1 When a rack fixation system is fitted, the design will be subject to special consideration.

■ *Section 4* Construction

4.1 Assembly design

4.1.1 The individual jacking gear units are to be designed such that each unit can be removed separately for inspection, maintenance and repair. Adequate arrangements for dismantling, including lifting devices, are to be provided.

4.1.2 Unless otherwise agreed, all gearing, except the main climbing pinion, are to operate in oil bath enclosures. Main pinions and racks are to be supplied with a suitable lubricant during all jacking operations.

4.1.3 Adequate inspection openings are to be provided to enable the teeth of pinions and gear wheels, and their attachment to the shafts, to be readily examined.

■ *Section 5* Inspection and testing

5.1 At jacking machinery manufacturers' works

5.1.1 The complete, assembled, jacking gear unit is to be subjected to a partial load running test with the first assembly for each new building tested to the maximum design jacking load (a minimum of one complete revolution of the main pinion) and the maximum static pre-load holding.

5.1.2 Upon satisfactory testing of the first jacking gear unit, the assembly is to be disassembled for inspection of all main components.

5.2 At the offshore unit construction site

5.2.1 Inspection and testing during construction and assembly is to be carried out to a plan/schedule acceptable to LR, but is to include the following:

(a) Jacking trials to verify satisfactory operation of the jacking machinery at all design jacking and holding load conditions.

(b) Jacking of hull/legs to the full extent of design travel to demonstrate satisfactory alignment of leg, racks, pinions and guides.

(c) Operation of the fixation system at various positions of leg/hull travel.

(d) Operation of the braking devices at the maximum design load to verify effective holding without slippage.

■ *Section 6* Operation in ice

6.1 Additional requirements

6.1.1 *See* Pt 3, Ch 6 for additional requirements for operation in ice.

Rules and Regulations for the Classification of Offshore Units

Part 6
Control and Electrical Engineering

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Chapter Contents

Part 6

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Section 1 General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to all offshore units defined in Pt 1, Ch 2. Where applicable, the relevant requirements for control, alarm and safety systems as stated in Pt 6, Ch 1 of the Rules for Ships are to be complied with.

1.1.2 Control engineering systems are to:

- provide control of required services and habitability requirements during defined operational conditions;
- provide control of the engineering systems necessary to ensure availability of essential and emergency safety systems during all normal and reasonably foreseeable abnormal conditions;
- provide control of the engineering systems necessary to ensure transitional power supplies remain available;
- be suitably protected against damage to itself under fault conditions and to prevent injury to personnel; and
- not fail in a way which may cause machinery and systems located in hazardous areas to create additional fire or explosion risk.

1.1.3 These requirements apply to manned offshore units. Special consideration will be given to unmanned offshore units which are controlled from the shore or from another offshore installation.

1.1.4 Where reference is made in this Chapter to the requirements of the Rules for Ships, references therein to 'ship(s)' are to be understood to apply to 'unit(s)'.

1.2 Documentation required for design review

1.2.1 The documentation described in 1.2.2 to 1.2.9 is to be submitted for design review.

1.2.2 Where control, alarm and safety systems are intended for machinery or equipment as defined in 1.2.3, the documentation stated in Pt 6, Ch 1,1.2.2 of the Rules for Ships is to be submitted.

1.2.3 Documentation for the control, alarm and safety systems of the following is to be submitted as applicable:

(a) **Propulsion and positioning systems**:
- Controllable pitch propellers.
- Dynamic positioning systems.
- Positional mooring and single point mooring systems.
- Propelling machinery including essential auxiliaries.
- Steering gear.
- Thruster-assisted positional mooring systems.
- Thruster units.

(b) **Utilities and services**:
- Air compressors.
- Bilge and ballast systems.
- Diving systems including compression chambers.
- Electric generating plant.
- Fixed water based local application fire-fighting systems.
- Evaporating and distilling systems.
- General service plant air and control and instrument air systems.
- Heating Ventilation and Air Conditioning (HVAC) systems including arrangements provided in respect of 1.3.3.
- Incinerators.
- Inert gas generators.
- Main propelling machinery including essential auxiliaries.
- Lifting appliances.
- Mechanical refrigeration systems.
- Oil fuel transfer and storage (purifiers and oil heaters).
- Oily water separators.
- Steam raising plant (boilers and their ancillary equipment).
- Cargo and ballast pumps in hazardous areas.
- Tempered water systems.
- Waste heat boiler.
- Windlasses.
- Valve position indicating systems, *see* 2.7.
- Miscellaneous machinery or equipment (where control, alarm and safety systems are specified by other Sections of the Rules).
- Cargo tank, storage tank, ballast tank and void space instrumentation where specified by other Sections of the Rules (e.g., water ingress detection, gas detection).
- Thermal fluid heaters.

(c) **Process plant equipment**:
- Coalescers, skimmers and dehydrators.
- Export pumps and compressors.
- Gas compressors.
- Gas lift systems.
- Glycol contactors and regenerators.
- Heat exchangers.
- HP and LP flare systems.
- Process analysers.
- Production and test separator vessels.
- Production transfer and storage systems.
- Sand detection systems.

- Scrubbers.
- Sphere launching and receiving systems.
- Surge, flash and knock out drums.
- Water, gas and chemical injection systems.
- Well head, choke and header systems.
- Wireline systems.

(d) **Drilling plant equipment**:
- Blow out preventer stacks and diverter systems.
- Cement and barytes storage and handling systems.
- Choke and kill systems.
- Drawworks and eddy current brakes.
- Mud logging systems.
- Mud and cement pumps.
- Mud treatment systems.
- Rotary table.
- Wireline systems.

(e) **Riser systems**.

1.2.4 **System operational concept**. A description of how the control, alarm and safety systems for the main and auxiliary machinery and systems essential for the propulsion and safety of the unit provide effective means for operation and control during all unit operational conditions.

1.2.5 **Alarm systems**. Details of the overall alarm system, linking the main control station, subsidiary control stations, workstation(s) for navigation and manoeuvring and where applicable, the bridge area, the accommodation and other areas where duty personnel may be present are to be submitted.

1.2.6 **Programmable electronic systems**. In addition to the documentation required by 1.2.2 and Pt 6, Ch 1,1.2.6 of the Rules for Ships, details of self-monitoring techniques are to be submitted.

1.2.7 **Wireless data communication**. For wireless data communication equipment the documentation required by Pt 6, Ch 1,1.2.7 of the Rules for Ships is to be submitted.

1.2.8 **Control stations**. Documentation required to be submitted is given in Pt 6, Ch 1,1.2.8 of the Rules for Ships.

1.2.9 **Approved system**. Where it is intended to employ a standard system which has been previously approved, documentation is not required to be submitted, providing there have been no changes in the applicable Rule requirements. The building port, where applicable, the specific project and date of the previous approval are to be advised.

1.3 Control, alarm and safety equipment

1.3.1 The requirements for control, alarm and safety equipment are given in Pt 6, Ch 1,1.3 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.3.2 For fire and gas detection alarm systems, *see* Pt 7, Ch 1,2.2 and for programmable electronic systems, *see* Pt 6, Ch 1,2.10.5 and Pt 6 Ch 1,2.13.3 of the Rules for Ships.

1.3.3 Where equipment requires a controlled environment, alternative arrangements, whether permanently installed or of a temporary nature, are to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see also* Table 14.12.4 in Pt 5, Ch 14,12 of the Rules for Ships. Details of these arrangements are to be submitted for consideration.

1.4 Alterations and additions

1.4.1 The requirements for alterations and additions are given in Pt 6, Ch 1,1.4 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.4.2 For ESD systems, *see* Pt 7, Ch 1,7, software modifications are to be undertaken in accordance with IEC 61508-1:2010, *Functional safety of electrical/electronic/ programmable electronic safety-related systems – Part 1: General requirements*, Section 7.16, or alternative relevant International or National Standard.

1.5 Definitions

1.5.1 Definitions are given in Pt 6, Ch 1,1.5 of the Rules for Ships, which are to be complied with.

■ *Section 2* Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the equipment defined in 1.2.3, the applicable features contained in Pt 6, Ch 1,2.1 of the Rules for Ships are to be incorporated in the system design.

2.2 Control stations for machinery and equipment

2.2.1 The requirements for control stations for machinery and equipment are given in Pt 6, Ch 1,2.2 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.2.2 Means of communication are to be provided as applicable between the main control station, subsidiary stations, the workstation(s) for navigation and manoeuvring, the bridge area where applicable, the unit manager's office, the drill floor, the tool pusher's office and the accommodation for operating personnel.

2.2.3 For requirements regarding general emergency alarm systems, *see also* Pt 7, Ch 1,3.3.

2.3 Alarm systems

2.3.1 The general requirements for alarm systems are given in Pt 6, Ch 1,2.3 of the Rules for Ships, which are to be complied with as required.

2.4 Safety systems

2.4.1 Where safety systems are provided the requirements of Pt 6, Ch 1,2.4 of the Rules for Ships are to be satisfied. The requirements of this sub-Section apply, where relevant, to the safety systems installed on the equipment defined in 1.2.3, including those safeguards required by Part 5. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.4.2 For emergency shut-down systems, *see also* Pt 7, Ch 1,7.

2.5 Control systems, general requirements

2.5.1 The requirements for control systems are given in Pt 6, Ch 1,2.5 of the Rules for Ships, which are to be complied with.

2.6 Control for main propulsion machinery

2.6.1 Where a control system for propulsion machinery is to be fitted, the requirements of Pt 6, Ch 1,2.6 of the Rules for Ships are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTES

1. The workstation(s) for navigation and manoeuvring will be located on the bridge of the unit, where such is provided. Where there is no designated bridge area, the requirements of this sub-Section remain applicable to the workstation(s) for navigation and manoeuvring, wherever their location.
2. Where separate workstations are provided for navigation and for manoeuvring, the requirements of this Section, and those of 4.2, are applicable to the former.
3. Where the Rules for Ships refer to ‘bridge control system’, this should be understood to apply to propulsion control system.

2.6.2 Instrumentation to indicate the following is to be fitted at the workstation(s) for navigation and manoeuvring:

(a) Propeller speed.
(b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for controllable pitch propeller, *see also* Pt 5, Ch 7,5 of the Rules for Ships.
(c) Direction and magnitude thrust.
(d) Clutch position, where applicable.
(e) Shaft brake position, where applicable.
(f) For an azimuth thruster, direction and magnitude of thrust, and alarms and indications as detailed in Table 20.4.1 in Pt 5, Ch 20 of the Rules for Ships.

2.6.3 Azimuth thrust direction is to be controlled from the workstation(s) for navigation and manoeuvring, under all sea-going and manoeuvring conditions.

2.6.4 Two means of communication are to be provided between the workstation(s) for navigation and manoeuvring and the main control station in the machinery space. One of these means may be the propulsion control system; the other is to be independent of the main electrical power supply, *see also* 2.2.2 and Pt 5, Ch 1,4.7 of the Rules for Ships.

2.7 Valve control systems

2.7.1 The requirements for valve control systems are given in Pt 6, Ch 1,2.7 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.7.2 For ballast controls of column-stabilised units, *see also* 2.8.

2.7.3 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Pt 4, Ch 7,10.

2.8 Ballast control systems for column-stabilised units

2.8.1 Column-stabilised units are to be provided with a ballast control system which meets the requirements of 2.8.2 to 2.8.8. The requirements for intact and damage stability and related definitions used in this Section are given in Pt 4, Ch 7, to which reference should be made.

2.8.2 A centralised ballast control station is to be provided from which all ballast operations can be performed. It is to be situated above zones of immersion after damage, as high as possible, as near a central position on the unit as is practicable, and adequately protected from the weather.

2.8.3 Control and instrumentation for the following is to be provided at the centralised control station:

(a) Ballast pump stop/start arrangements, status indicators, and control facilities.
(b) Ballast valve controls and position indication.
(c) Ballast tank level indication.
(d) Tank level indication of all tanks containing quantities of liquid that could affect stability of the unit, including fuel oil, fresh water, drilling water, and other stored liquids.
(e) Unit draught, heel and trim indication.
(f) Remote controls and indicators for watertight doors and hatch covers and other closing appliances, *see* Pt 7, Ch 1,10.
(g) Bilge and flood alarms, *see* Pt 7, Ch 1,10.
(h) Mooring line tension indication.

2.8.4 A permanently installed means of communication, independent of the unit’s main source of electrical power, is to be provided between the centralised ballast control station and spaces that contain ballast pumps and services necessary for ballast operations, including local hand controls called for in 2.8.5.

2.8.5 In addition to the centralised controls required by 2.8.3(a) and (b), permanently installed local controls are to be provided to allow operation in the event of failure of the centralised controls.

2.8.6 The independent local controls for each ballast pump and its associated ballast tank valves are to be located in the same location, and a diagram of that part of the system is to be permanently displayed at the local control position.

2.8.7 The local controls are to be in readily accessible positions, and the associated access routes are to be situated inboard of the penetration zones after defined damage, *see* Pt 4, Ch 7,3.2. They are also to remain accessible and protected from the weather when the unit is in the intact and damaged condition.

2.8.8 Valve controls are to comply with 2.7 and, in addition, remote valve position indication systems are to function as independently as practicable of the control systems, *see also* Pt 5, Ch 13,5 and particularly Pt 5, Ch 13,5.4.

2.9 Programmable electronic systems – General requirements

2.9.1 The requirements for programmable electronic systems are given in Pt 6, Ch 1,2.10 of the Rules for Ships, which are to be complied with.

2.10 Data communication links

2.10.1 The requirements for data communication links are given in Pt 6, Ch 1,2.11 of the Rules for Ships, which are to be complied with.

2.11 Additional requirements for wireless data communication links

2.11.1 The requirements for wireless data communication links are given in Pt 6, Ch 1,2.12 of the Rules for Ships, which are to be complied with. The requirements are in addition to 2.10 and apply to systems incorporating wireless data communication links.

2.12 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.12.1 The requirements for programmable electronic systems incorporated in control, alarm or safety systems for essential services, as defined by Pt 6, Ch 2,1.6 or safety critical systems, are given in Pt 6, Ch 1,2.13 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.12.2 Input and output connections for safety critical systems (including emergency shut-down push button signals) are to be hard-wired, unless shown to meet the relevant requirements of Pt 7, Ch 1,7, for emergency shut-down systems. The transmission of the alarm and status information by digital means between the system and the supervisory workstation is permissible.

2.13 Programmable electronic systems – Additional requirements for integrated systems

2.13.1 The additional requirements for programmable electronic systems for integrated systems are given in Pt 6, Ch 1,2.14 of the Rules for Ships, which are to be complied with.

■ *Section 3*
Ergonomics of control stations

3.1 Control station layout

3.1.1 In order to take account of operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in Pt 6, Ch 1,3.2 of the Rules for Ships.

3.2 Physical environment

3.2.1 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst operators at main control stations, the requirements in Pt 6, Ch 1,3.3 of the Rules for Ships, are to be complied with.

3.3 Operator interface, controls, display

3.3.1 The requirements in Pt 6, Ch 1,3.4 to 3.6 of the Rules for Ships apply to operator interfaces for essential engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

Section 4
Unattended machinery space(s) – UMS notation

4.1 General

4.1.1 The general requirements for unattended machinery space(s) are given in Pt 6, Ch 1,4.1 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.1.2 The requirements of this Section apply to all types of thrusters incorporated in the propulsion or positioning systems of the unit.

4.1.3 For this Section where the Rules for Ships refer to ‘bridge’, this is to be understood to apply to workstation(s) for navigation and manoeuvring, the bridge, if fitted or otherwise a continuously attended control station, as appropriate for the operating condition of the unit.

4.1.4 For this Section where the Rules for Ships refer to ‘engineering personnel’, this is to be understood to apply to maintenance personnel.

4.2 Alarm system for machinery

4.2.1 The requirements for the alarm system for machinery are given in Pt 6, Ch 1,4.2 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.2.2 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

4.3 Remote control of propulsion machinery

4.3.1 Where propulsion machinery is installed, it is to be provided with a remote control system operable at the workstation(s) for navigation and manoeuvring. The system is to satisfy the requirements of 2.6.

4.4 Control stations for machinery

4.4.1 Control station(s) are to be provided in the vicinity of the propulsion machinery and at workstation(s) for navigation and manoeuvring, and are to satisfy the requirements of 2.2.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted to protect all unattended spaces together with an audible and visual alarm system. The system is to satisfy the requirements of Pt 7, Ch 1,2.

4.6 Bilge level detection

4.6.1 The requirements for bilge level detection are given in Pt 6, Ch 1,4.6 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.6.2 A minimum of two independent systems of bilge level detection is to be provided in each machinery space that is situated below the water line. In addition each branch bilge as required by Pt 5, Ch 13,4 of the Rules for Ships is to be provided with a level detector.

4.7 Supply of electric power – General

4.7.1 For units which operate with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For units operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see* Ch 2,2.2.

Section 5
Machinery operated from a centralised control station – CCS notation

5.1 General requirements

5.1.1 The requirements for machinery operated from a centralised control station are given in Pt 6, Ch 1,5.1 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.1.2 The controls, alarms and safeguards required by Part 5 and by 4.6 together with a fire detection system satisfying the requirements of Pt 7, Ch 1,2 are to be provided. However, the automatic operation of machinery and certain safeguards required by Part 5 may be omitted. Where such safeguards are omitted, due consideration is to be given to the reaction time required for manual intervention, following indication that a system or equipment has deviated outside acceptable operational limits.

5.2 Centralised control system for machinery

5.2.1 The requirements for a centralised control system for machinery are given in Pt 6, Ch 1,5.2 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.2.2 In addition to the communication required by Pt 6, Ch 1,5.2.5 of the Rules for Ships, a second means of communication is to be provided between the workstation(s) for navigation and manoeuvring and the centralised control station. One of these means is to be independent of the main electrical power supply, *see also* Pt 5, Ch 1 of the Rules for Ships.

■ *Section 6* Integrated computer control – ICC notation

6.1 General

6.1.1 Integrated Computer Control class notation **ICC** may be assigned where an integrated computer system in compliance with Pt 6, Ch 1,6 of the Rules for Ships provides fault tolerant control and monitoring functions for one or more of the following services:

- Propulsion and auxiliary machinery.
- Dynamic positioning systems.
- Positional mooring systems.
- Ballast systems.
- Process and utilities.
- Drilling equipment.
- Product storage and transfer systems.

Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.1.2 Pt 6, Ch 1,6.1.3 of the Rules for Ships is not applicable to offshore units.

6.2 General requirements

6.2.1 The general requirements for integrated computer control systems are given in Pt 6, Ch 1,6.2 of the Rules for Ships. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.2.2 The integrated computer control system is to comply with the programmable electronic system requirements of 2.9 to 2.13 and the control and monitoring requirements of the Rules applicable to particular equipment, machinery or systems.

6.2.3 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system, *see also* Pt 6, Ch 1,2.14 of the Rules for Ships.

6.2.4 Controls are to be provided, in compliance with 2.5.

6.3 Operator stations

6.3.1 The requirements for the operator stations are given in Pt 6, Ch 1,6.3 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.3.2 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g., in control, standby, etc.) is to be clearly indicated, *see also* 2.2.

■ *Section 7* Functional testing

7.1 General

7.1.1 The general requirements for the functional tests are given in Pt 6, Ch 1,7.1 of the Rules for Ships, which are to be complied with.

7.2 Unattended machinery space operation – UMS notation

7.2.1 In addition to the tests required by 7.1, the requirements for the functional tests of **UMS** notation during final commissioning sea trials are given in Pt 6, Ch 1,7.2 of the Rules for Ships, which are to be complied with.

7.3 Operation from a centralised control station – CCS notation

7.3.1 In addition to the tests required by 7.1, the requirements for the functional tests of **CCS** notation during final commissioning sea trials are given in Pt 6, Ch 1,7.3 of the Rules for Ships, which are to be complied with.

7.4 Record of trials

7.4.1 The requirements for the records of the trials are given in Pt 6, Ch 1,7.4 of the Rules for Ships, which are to be complied with.

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to all offshore units defined in Pt 1, Ch 2 except where otherwise stated. Where applicable, the relevant requirements for electrical services necessary to maintain the unit in a normal sea-going, operational and habitable condition, for electrical services essential for safety and for the safety of crew and unit from electrical hazards as stated in Pt 6, Ch 2 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) are to be complied with.

1.1.2 Attention is also to be given to any relevant statutory regulation of the National Administration in the country in which the unit is to operate and/or be registered.

1.1.3 Where reference is made to the requirements of the Rules for Ships, references therein to 'ship(s)' are to be understood to refer to 'unit(s)'.

1.2 Documentation required for design review

1.2.1 The documentation in Pt 6, Ch 2,1.2 of the Rules for Ships is to be submitted for consideration. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTE
Where reference is made in the Rules for Ships to explosive gas atmospheres and/or combustible dusts, or to the electrical equipment for use in those areas, *see also* Pt 7, Ch 2,8 and Ch 2,9.

1.2.2 Electrical system study and calculations are to be in accordance with the IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 9, or an alternative relevant International or National Standard.

1.2.3 The general arrangement of the unit, showing the hazardous zones and spaces, is to include details on the permitted temperature class and gas group of the electrical equipment. The temperature class and apparatus group of the electrical equipment are associated with the ignition temperature and energy required for ignition of the hazardous substances.

1.3 Documentation required for supporting evidence

1.3.1 The documentation and particulars in Pt 6, Ch 2,1.3 of the Rules for Ships are to be submitted as supporting evidence. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.3.2 A description of the philosophy of the systems of power generation and distribution, describing their modes of operation under normal and emergency conditions, is to be submitted.

1.3.3 Arrangement plans of main and emergency switchboards, section boards, and documentation that demonstrates that creepage and clearance distances are in accordance with 7.5. The form factor of internal separation of low voltage switchgear and control gear assemblies is to be in accordance with IEC 61439-2, *Low-voltage switchgear and control gear assemblies – Part 2: Power switchgear and control gear assemblies*, or alternative relevant International or National Standards. The form factor is to be stated, and the arrangement plans are to show how the form factor has been achieved.

1.4 Surveys

1.4.1 The equipment required to be surveyed is given in Pt 6, Ch 2,1.4 of the Rules for Ships, which are to be complied with.

1.5 Additions or alterations

1.5.1 The requirements for additions or alterations are given in Pt 6, Ch 2,1.5 of the Rules for Ships, which are to be complied with.

1.6 Definitions

1.6.1 Definitions are given in Pt 6, Ch 2,1.6 of the Rules for Ships and in IEC 61892-1:2010, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*, Section 3. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.6.2 Essential services are those necessary for the propulsion and safety of the unit, such as the following:

- Items as given in Pt 6, Ch 2,1.6.1 of the Rules for Ships;
- Thruster systems for positional mooring;
- Abandonment systems dependent on electric power;
- Ventilation systems for hazardous areas and those maintained at an overpressure to exclude the ingress of dangerous gases;
- Wellhead control and disconnection systems dependent on electric power.

1.6.3 Services considered necessary for minimum comfortable conditions of habitability are given in Pt 6, Ch 2,1.6.2 of the Rules for Ships.

1.6.4 Services such as the following, which are additional to those in 1.6.2 and 1.6.3, are considered necessary to maintain the unit in a normal and sea-going operation and habitable condition:

- Drilling plant equipment;
- Processing and production equipment;
- Hotel services, other than those required for habitable conditions;
- Thrusters, other than those for essential services; and
- Lifting appliances for the transfer of material, equipment or personnel.

1.7 Design and construction of equipment

1.7.1 The requirements for design and construction are given in Pt 6, Ch 2,1.7 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.7.2 Equipment or apparatus required to be suitable for use in an explosive gas atmosphere shall comply with the requirements of Pt 7, Ch 2, Sections 8, 9, 10 and 11, IEC 60092-502, *Electrical installations in ships – Part 502: Tankers – Special features*, IEC 61892-7, *Mobile and fixed offshore units – Electrical installations – Part 7: Hazardous areas* or alternative relevant International or National Standard. Such equipment shall be constructed and tested in accordance with the requirements of the IEC 60079 series, *Explosive atmospheres* (or alternative relevant International or National Standard) and be fit for purpose for the actual ambient temperature and other environmental conditions.

1.8 Quality of power supplies

1.8.1 The requirements for quality of power supplies are given in Pt 6, Ch 2,1.8 of the Rules for Ships and IEC 61892-1:2010, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*, Section 4.7, which are to be complied with.

1.9 Ambient reference and operating conditions

1.9.1 The requirements for ambient reference and operating conditions are given in Pt 6, Ch 2,1.9 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.9.2 The rating for classification purposes of essential electrical equipment is to be based on the maximum ambient air and water temperatures expected at the location of the unit. In the absence of precise temperatures, the following temperatures are to be assumed:

(a) For units intended to operate within the tropical belt (i.e., between latitudes 35°N and 20°S):
Primary cooling water supply 32°C
Cooling air temperature 45°C.

(b) For units intended to operate in northern or southern waters outside the tropical belt:
Primary cooling water supply 25°C
Cooling air temperature 40°C.

1.9.3 The air temperature range considered with respect to the selection of equipment, the safe operation of which may be subject to limitations on ambient temperature (e.g., safe type electrical equipment), is to be that expected at the location of the equipment, taking into account local sources of heat and the range of ambient air temperature expected at the location of the unit. In the absence of precise information, the maximum air temperature is to be assumed to be that of the cooling air temperature given in 1.9.2(a) or (b), as appropriate, and the minimum is to be assumed to be minus 20°C, or as determined by reference to Annex B of IEC 61892-1, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*.

1.9.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not more than 10°C below that determined by reference to 1.9.2 or 1.9.3, provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by an independent and redundant cooling unit(s) so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safely within the cooling temperature (*see* 1.9.2(a) and (b)) until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than the cooling temperature (*see* 1.9.2(a) and (b)); and
- alarms are provided, at a continuously attended control station, to indicate any malfunction of the cooling units. *See also* Ch 1,1.3.3.

1.9.5 Where equipment is to comply with 1.9.4, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.9.6 Items of equipment used for cooling and maintaining the lesser ambient temperature in accordance with 1.9.4 are considered essential services and are to satisfy the requirements of 5.2.

1.10 Inclination of the unit

1.10.1 The requirements for inclination of the unit are given in Pt 6, Ch 2,1.10 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.10.2 Essential and emergency electrical equipment is to operate satisfactorily under the conditions as shown in Table 2.1.1 for column-stabilised, tension-leg and self-elevating units. For buoy and deep draught caisson units, the angles of inclination will be specially considered in each case.

Table 2.1.1 Inclination of other units

Installations, components	Angle of inclination, degrees in any direction			
	Column-stabilised units		Self-elevating units	
	Static	Dynamic	Static	Dynamic
Essential electrical equipment	15	22,5	10	15
Electrical equipment for emergency services	25	25	15	15

1.11 Location and construction of equipment

1.11.1 The requirements for location and construction are given in IEC 61892-1:2010, *Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions*, Sections 4.15 to 4.20 and Pt 6, Ch 2,1.11 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.11.2 Electrical equipment, as far as is practicable, is to be located:

(a) Such that it is accessible for the purpose of maintenance and survey;
(b) Clear of flammable material;
(c) In spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.9;
(d) Where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to comply with the relevant requirements of Pt 7, Ch 2,8;
(e) Where it is not exposed to the risk of mechanical injury or damage from water, steam or oil; and
(f) Clear of areas at risk of cryogenic spills.

1.11.3 Equipment located in hazardous areas, or required to remain operational during catastrophic conditions, is to comply with the relevant requirements of Pt 7, Ch 2,8.

1.11.4 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.10 for essential electrical equipment, *see also* Pt 5, Ch 13.

1.12 Earthing of non-current-carrying parts

1.12.1 The requirements for earthing of non-current-carrying parts are given in Pt 6, Ch 2,1.12 of the Rules for Ships and IEC 61892-6:2007 Section 4 *Mobile and fixed offshore units – Electrical installations – Part 6: Installation* which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.12.2 Where the current-carrying conductor exceeds 120 mm^2, a 70 mm^2 earthing conductor is permitted, provided that the circuit protection arrangements are such as will prevent an excessive temperature rise under fault conditions.

1.13 Bonding for the control of static electricity

1.13.1 The requirements for bonding for the control of static electricity are given in Pt 6, Ch 2,1.13 of the Rules for Ships, IEC 60092-502:1999, *Electrical installations in ships – Part 502: Tankers – Special features*, Section 5.5 and IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation*, Section 4, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.13.2 Bonding straps for the control of static electricity are required for storage tanks, process plant and piping systems located in hazardous areas, or for flammable products and solids liable to release flammable gas and/or combustible dust, which are not permanently connected to the structure of the unit either directly or via their bolted or welded supports and where the resistance between them and the structure exceeds 1MΩ.

1.14 Alarms

1.14.1 The requirements for alarms are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 12.12.2.4 and Pt 6, Ch 2,1.14 of the Rules for Ships which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

1.14.2 Cables for emergency alarms and their power sources are to be in accordance with 1.16.

1.14.3 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, cryogenic spill, collision, flooding or similar damage is minimised, *see* 1.16, 1.17 and Pt 11, Ch 5, LR 5.14.

1.15 Labels, signs and notices

1.15.1 The requirements for labels, signs and notices are given in Pt 6, Ch 2,1.15 of the Rules for Ships, which are to be complied with.

1.16 Operation under fire conditions

1.16.1 The requirements for operation under fire conditions are given in Pt 6, Ch 2,1.16 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTE

- For fire safety stops, *see also* Pt 7, Ch 1,2.4.
- For low location lighting, *see also* Pt 7, Ch 1,3.5.

1.16.2 The following emergency services and their emergency power supplies are also required to be capable of being operated under fire conditions:

- Emergency Shut-down (ESD) systems, *see* Pt 7, Ch 1,7.
- Emergency Release Systems (ERS), *see* Pt 7, Ch 1,8.

1.17 Operation under flooding conditions

1.17.1 The requirements for operation under flooding conditions are given in Pt 6, Ch 2,1.17 of the Rules for Ships, which are to be complied with.

1.18 Protection of electrical equipment against the effects of lightning strikes

1.18.1 The requirements for protection of electrical equipment against the effects of lightning strikes are given in Pt 6, Ch 2,1.18 of the Rules for Ships, which are to be complied with.

1.19 Programmable electronic systems

1.19.1 The requirements for programmable electronic systems are given in Pt 6, Ch 2,1.19 of the Rules for Ships, which are to be complied with.

■ *Section 2* Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to include at least two generating sets and is to comply with the requirements of this Section, Pt 6, Ch 2,2 of the Rules for Ships and IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 4 without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 The requirements for the number and rating of generators and converting equipment are given in Pt 6, Ch 2,2.2 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

NOTE

The requirements are applicable when a unit is changing its location (self-propelled or towed) or stationary engaged in its primary function (e.g., drilling, production or lifting, oil storage).

2.2.2 Under normal operating and sea-going conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment, habitable conditions. *See* Pt 6, Ch 2,16.3.5 of the Rules for Ships for electric propulsion systems;

(b) to have sufficient reserve capacity to permit the starting of the largest motor for essential services without causing any motor to stall or any device to fail due to excessive voltage drop on the system;

(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a dead ship condition. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3, *see also* 2.3.2.

2.2.3 Where the electrical power requirement to maintain the unit in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator, *see* 6.9. On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services, *see* 1.6.2, in as short a time as is practicable.

NOTE

Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The requirements for starting arrangements are given in Pt 6, Ch 2,2.3 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a dead ship condition, the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead ship condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in 3.2.4(a), 3.2.4(b)(i) and (ii), 3.2.4(c)(i) to (iv). *See* Pt 5, Ch 2,9.1.1 of the Rules for Ships for dead ship condition starting arrangements.

2.4 Prime mover governors

2.4.1 The requirements for prime mover governors are given in Pt 6, Ch 2,2.4 of the Rules for Ships, which are to be complied with.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 The requirements for generators and generator systems having the unit's propulsion machinery as their prime mover but not forming part of the unit's main source of electrical power are given in Pt 6, Ch 2,2.5 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

2.5.2 In addition to the requirements of 2.2.3, arrangements are to be fitted to start one of the generators forming the main source of power automatically should the frequency variations exceed those permitted by the Rules.

■ *Section 3* Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to units to be classed for unrestricted service. They do not apply to units of less than 500 tons gross tonnage. Alternative arrangements in accordance with the requirements of the National Administration may also be acceptable.

3.1.2 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, the installation is to comply with the requirements of 3.7.

3.1.3 The emergency source of power for units of less than 500 tons gross tonnage will be the subject of special consideration.

3.1.4 For emergency source of electrical power in accommodation units, *see* Pt 3, Ch 4,4.2.

3.2 Emergency source of electrical power

3.2.1 The general requirements for emergency source of electrical power are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 4 and Pt 6, Ch 2,3.3 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located in a non-hazardous space above the uppermost continuous deck and above the worst damage waterline, inboard of the damage zones, *see* Pt 4, Ch 7,2 and Ch 7,3. They are not to be located forward of the collision bulkhead, if any.

3.2.3 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of hazardous areas or machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.4 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of 18 hours, emergency lighting:
  (i) in alleyways, stairways and exits, giving access to the muster and embarkation stations:
  (ii) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift;
  (iii) in the machinery spaces and main generating stations including their control positions;
  (iv) in all control stations, machinery control rooms, and at each main and emergency switchboard;
  (v) at all stowage positions for fireman's outfits;
  (vi) at the steering gear;
  (vii) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;
  (viii) in any stored oil pump-room;
  (ix) at every survival craft preparation station, muster and embarkation station and over the sides;
  (x) on helicopter decks, to include deck perimeter lights and helideck status lights, wind direction indicator illumination, and related obstruction lights, if any;
  (xi) in all spaces from which control of the drilling process is performed and where controls of machinery essential for the performance of this process, or devices for emergency switching off of the power plant are located; and
  (xii) at ESD manual activation points.

(b) For a period of 18 hours:
  (i) the navigation lights and other lights and sound signals required by the *International Regulations for the Prevention of Collisions at Sea* in force;
  (ii) the radio communications as required by Amendments to SOLAS 1974, Chapter IV;
  (iii) permanently installed diving equipment necessary for the safe conduct of diving operations, if dependent upon the unit's electrical power;
  (iv) the emergency fire pump if dependent upon the emergency generator for its source of power;
  (v) one of the refrigerated liquid carbon dioxide units intended for fire protection, where both are electrically driven;
  (vi) on column-stabilised units: ballast pump control system, ballast pump status-indicating system, ballast valve control system, ballast valve position indicating system, draft level indicating system, tank level indicating system, heel and trim indicators, power availability indicating system (main and emergency), ballast system hydraulic/pneumatic pressure-indicating sytem and the largest capacity ballast pump required by Pt 5, Ch 13,11 of the Rules for Ships; and
  (vii) abandonment systems dependent on electric power.

(c) For a period of 18 hours:
  (i) the navigational aids as required by Amendments to SOLAS 1974 Regulations V/19 as applicable;
  (ii) general alarm and communication systems required in an emergency;
  (iii) intermittent operation of the daylight signalling lamp and the unit's whistle, the manually operated call points and all internal signals that are required in an emergency;
  (iv) the fire and gas detection systems and their alarms; and
  (v) the capability of closing the blow out preventer and of disconnecting the unit from the wellhead arrangement, if electrically controlled, unless such services have an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of 18 hours.

(d) The steering gear for the period of time required by Pt 5, Ch 19,6 of the Rules for Ships.

(e) For a period of four days, any signalling lights or sound signals which may be required for marking offshore structures, unless such services have an independent supply from an accumulator battery suitably located for use in an emergency and sufficient for the period of four days.

(f) For a period of half an hour:
  (i) power to operate any watertight doors but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided; and
  (ii) power to operate the controls and indicators provided.

(g) Where applicable, the services required by Pt 6, Ch 2,2.3.2.

(h) For a minimum of 30 minutes, the ESD system with its indication circuits as required by Pt 7, Ch 1,7.1.10.

3.2.5 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed-cup test) of not less than 43°C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.2.6 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.2.6 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.2.6 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the

battery throughout the discharge period within 12 per cent above or below its nominal voltage;

(ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

(iii) immediately supplying at least those services specified in 3.2.6.

3.2.6 The transitional source of emergency electrical power where required by 3.2.5 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.2.4(a) and 3.2.4(b). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by 3.2.4(c)(ii), (iii), (iv) and (v) and 3.2.4(h) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

3.3 Starting arrangements

3.3.1 The requirements for starting arrangements are given in Pt 6, Ch 2,3.4 of the Rules for Ships, which are to be complied with.

3.4 Prime mover governor

3.4.1 The requirements for prime mover governor are given in Pt 6, Ch 2,3.5 of the Rules for Ships, which are to be complied with.

3.5 Radio installation

3.5.1 The requirements for radio installation are given in Pt 6, Ch 2,3.6 of the Rules for Ships, which are to be complied with.

3.6 Accommodation units

3.6.1 The emergency source of electrical power in units carrying more than 50 persons, who are not crew members or passengers, is to comply with the requirements of Pt 3, Ch 4,4.

3.7 Alternative sources of emergency electrical power

3.7.1 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, the installation is to meet the requirements of this sub-Section.

3.7.2 The main sources of electrical power are to be:

(a) separated and located in two or more compartments that are not contiguous with each other;

(b) self-contained and arranged to be independent such that each system can operate without recourse to the other main source(s) including power distribution and any associated converting equipment and control systems;

(c) arranged such that a fire or casualty in any one of the compartments will not affect the electrical power distribution from the other(s), or to the services required by 3.2.4;

3.7.3 The arrangements in each compartment referred to in 3.7.2 are to be equivalent to those under paragraphs 3.2.5(a) and Pt 6, Ch 2,3.3.12 to 3.3.14 of the Rules of Ships, so that a source of electrical power is available at all times to the services of 3.2.4.

3.7.4 The generator sets forming the main sources of electrical power referred to in 3.7.2, are to meet the provision of 1.10.2, with each generator having sufficient capacity to meet the requirements of paragraph 3.2.4, in each of at least two compartments.

3.7.5 The number and arrangements of generators is to allow for maintenance at sea of any one generator without affecting the ability to comply with 3.7.2.

3.7.6 Starting arrangements of main sources of electrical power are to comply with the requirements of Pt 5, Ch 2,9.4 of the Rules for Ships.

3.7.7 The location of each of the compartments referenced in 3.7.2 is to comply with 3.2.2 and the boundaries meet the provisions of 3.2.3.

3.7.8 Where these Rules specify that a service is required to be connected to both the main and emergency source of electrical power or is to be connected to the emergency switchboard, these services are to be served by at least two individual circuits from the separated main sources of electrical power with arrangements to transfer between the two sources. The supplies are to be separated in their switchboard and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single electrical fault will not cause the loss of both supplies.

3.7.9 Provision is to be made for periodic testing to demonstrate services required by 3.2.4 can be supplied automatically following the loss of one main source of electrical power.

3.7.10 To demonstrate compliance with the requirements of 3.7.2, 3.7.3 and 3.7.5 a risk assessment is to be carried out demonstrating that a single point failure such as a fire within a space would not render the systems incapable of supplying those services required in an emergency.

■ *Section 4* External source of electrical power

4.1 Temporary external supply

4.1.1 The requirements for temporary external supply are given in Pt 6, Ch 2,4.1 of the Rules for Ships, which are to be complied with where applicable.

4.2 Permanent external supply

4.2.1 The requirements for permanent external supply are given in Pt 6, Ch 2,4.2 of the Rules for Ships, which are to be complied with.

■ *Section 5* Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The requirements for systems of supply and distribution are given in Pt 6, Ch 2,5.1 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.1.2 The following systems of generation and distribution are acceptable:
(a) d.c., two-wire, insulated;
(b) a.c., single-phase, two-wire, insulated;
(c) a.c., three-phase; three-wire, insulated;
(d) earthed systems, a.c. or d.c.
The following neutral earthing methods are permitted:
- Directly earthed TN System.
- Impedance earthed IT System.
- Isolated IT System.

Earthing systems complying with IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 5 and IEC 60092-502:1999, *Electrical installations in ships – Part 502: Tankers – Special features*, Section 5 are acceptable.
While both insulated and earthed distribution systems (TN-S) are permitted, systems which may result in the presence of electrical currents within the hull or unit structure return (TN-C and TN-C-S) are not permitted, with the exception of:
- limited and locally earthed systems outside any hazardous area;
- intrinsically safe systems;
- impressed current cathodic protection systems.

NOTES
- IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Table 2 summarises the principal features of the neutral earthing methods.
- Systems installed in hazardous areas shall comply with the requirements of Pt 7, Ch 2, Sections 8, 9, 10 and 11.
- In hazardous areas (where inflammable gas may be present as defined in IEC 60092-502:1999, *Electrical installations in ships – Part 502: Tankers – Special features*, Section 4) a.c. systems are to be earthed to comply with IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*, in particular Section 6 'Protection from dangerous (incentive) sparking', and be arranged so that no current arising from an earth fault in any part of the system could pass through extraneous metalwork located in a hazardous area. Earthed intrinsically safe circuits are permitted to pass into and through hazardous areas.

5.2 Essential services

5.2.1 The requirements for essential services are given in Pt 6, Ch 2,5.2 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.2.2 Essential services that are required by Part 5 to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.3 Isolation and switching

5.3.1 The requirements for isolation and switching are given in Pt 6, Ch 2,5.3 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.3.2 Isolation and switching is to be by means of a circuit-breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:
(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short-circuit;
In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see* 6.5 and 7.3.

5.3.3 Devices selected for isolation of circuits up to and including 1000V a.c or 1500V d.c. shall comply with the relevant International or National Standards.

5.4 Insulated distribution systems (IT systems)

5.4.1 The requirements for insulated distribution systems are given in Pt 6, Ch 2,5.4 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.4.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power,

heating and lighting circuits, to monitor continuously the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance, *see also* Ch 1,4.2.

5.4.3 IT systems (neutral isolated from earth or earthed through a high impedance) shall meet the requirements of IEC 61892-2, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, IEC 60092-502, *Electrical installations in ships – Part 502: Tankers – Special features* and IEC 60079-14, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*.

5.5 Earthed distribution systems (TN systems)

5.5.1 The requirements for earthed distribution systems are given in Pt 6, Ch 2,5.5 of the Rules for Ships, which are to be complied with where applicable.

5.5.2 TN systems (directly earthed) shall meet the requirements of IEC 61892-2, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*. TN-C and TN-C-S systems are only permitted for the applications listed in 5.1.2.

5.6 High voltage distribution systems

5.6.1 For systems with nominal voltage 15 kV a.c., or greater, the neutral (star point) shall be earthed by one of the following methods:
(a) High impedance resistor.
(b) Earthing transformer.
The earth fault current should be as low as is reasonably practicable to allow the earth fault protection to operate in a time specified by the protection coordination study and to minimise touch voltages. Systems with resonant earthing (Petersen coil) are not permitted.

5.6.2 Earthing systems serving high voltage systems, including systems with nominal voltage 15 kV a.c. or greater, shall be solidly interconnected with the LV system earthing network to minimise touch voltages. The touch voltages and fault durations shall not exceed the values given in Annex B Touch Voltage and Body Current of BS EN 50522:2012, *Earthing of power installations exceeding 1 kV a.c*.
NOTE
Although offshore units are outside the scope of BS EN 50522, earthing of power installations exceeding 1 kV a.c. guidance on dangerous touch voltages and earthing system design may be obtained from this standard.

5.7 Diversity factor

5.7.1 The requirements for the diversity factor are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 8 and Pt 6, Ch 2,5.6 of the Rules for Ships, which are to be complied with.

5.8 Lighting circuits

5.8.1 The requirements for lighting circuits are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 11 and Pt 6, Ch 2,5.7 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.8.2 Escape lighting fittings supplied by a central battery system or UPS are to be connected to the power source using fire-resistant cables and comply with the relevant International or National Standards.

5.8.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other. One of these circuits may be an emergency circuit, provided it is normally energised, in which case the arrangements are to comply with Section 3.

5.8.4 Emergency lighting is to be fitted in accordance with Section 3, *see also* Pt 7, Ch 1,4.

5.8.5 Where lighting circuits in a stored oil pump-room adjacent to a storage tank are also used for emergency lighting, and have been interlocked with ventilation, the interlocking arrangements are:
- not to cause the lighting to go out following a failure of the ventilation system; and
- not to prevent operation of the emergency lighting following the loss of the main source of electrical power.

5.9 Motor circuits

5.9.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.6.2.

5.10 Motor control

5.10.1 The requirements for motor control are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 7.8 and Pt 6, Ch 2,5.9 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

5.10.2 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also* 6.10.

■ *Section 6* System design – Protection

6.1 General

6.1.1 The general requirements for protection are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10 and Pt 6, Ch 2,6.1 of the Rules for Ships, which are to be complied with.

6.2 Protection against short-circuit

6.2.1 The general requirements for protection against short-circuit are given in Pt 6, Ch 2,6.2 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit-breakers and fuses are detailed in 6.5 and 6.6 respectively.

6.3 Protection against overload

6.3.1 The general requirements for protection against overload are given in Pt 6, Ch 2,6.3 of the Rules for Ships, which are to be complied with.

6.4 Protection against earth faults

6.4.1 The general requirements for protection against short-circuit are given in Pt 6, Ch 2,6.4 of the Rules for Ships, which are to be complied with. For systems of 15 kV a.c. and above, *see also* 5.6. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.4.2 Where any circuit, other than an intrinsically safe circuit, passes into or through any Zone 0 area, the circuit is to be disconnected automatically and/or is to be prevented from being energised in the event of an abnormally low level of insulation resistance and/or high level of leakage current.

6.4.3 Where a circuit passes into any zone 0 area, the protective systems shall be arranged so that manual intervention is necessary for the reconnection of the circuit after disconnection as the result of a short-circuit, overload or earth-fault condition.

6.5 Circuit-breakers

6.5.1 The requirements for circuit-breakers are given in Pt 6, Ch 2,6.5 of the Rules for Ships, which are to be complied with.

6.6 Fuses

6.6.1 The requirements for fuses are given in Pt 6, Ch 2,6.6 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.6.2 The use of fuses for overload protection is permitted up to 320A, provided they have suitable characteristics, but the use of circuit-breakers or similar devices is recommended above 200A. For high voltage a.c. systems (above 1 kV a.c.), the use of fuses for overload protection is not acceptable.

Is Limiters

The use of Is Limiters is permitted in situations where circuit-breakers cannot provide any protection against unduly high peak short-circuit currents, as circuit-breakers are too slow.

NOTE

Only the Is Limiter is capable of detecting and limiting a short-circuit current at the first rise, i.e., in less than 1 ms. The maximum instantaneous current occurring remains well below the level of the peak short-circuit current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The requirements for circuit-breakers requiring back-up by fuse or other devices are given in Pt 6, Ch 2,6.7 of the Rules for Ships and IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations –- Part 2: System design*, Section 10.2.3, which are to be complied with.

6.8 Protection of generators

6.8.1 The requirements for the protection of generators are given in Pt 6, Ch 2,6.8 of the Rules for Ships and IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.2, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multipole linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Where generators are intended to operate in parallel:

(a) Generators are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cables between the generator and its circuit-breaker, will instantaneously open the circuit-breaker and de-excite the generator.

(b) Under-voltage protection shall be provided to prevent the generator circuit-breaker from closing if the generator is not generating, in accordance with Section 10.5.1 of IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*.

6.9 Load management

6.9.1 The requirements for load management are given in IEC 61892-5:2010, *Mobile and fixed offshore units – Electrical installations – Part 5: Mobile units*, Section 9.9.2, IEC 60092-504, *Electrical installations in ships – Part 504: Special features – Control and instrumentation* and Pt 6, Ch 2,6.9 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

6.9.2 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded, sufficient to ensure the connected generating set(s) is/are not overloaded:

- non-essential circuits;
- circuits feeding services for habitability, *see* Pt 6, Ch 2,1.6.2 of the Rules for Ships; and
- circuits for other essential services, when it can be established that safe operation can be maintained during the temporary loss of such services.

6.10 Feeder circuits

6.10.1 The requirements for feeder circuits are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.5 and Pt 6, Ch 2,6.10 of the Rules for Ships, which are to be complied with.

6.11 Motor circuits

6.11.1 The requirements for motor circuits are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.6 and Pt 6, Ch 2,6.11 of the Rules for Ships, which are to be complied with.

6.12 Protection of transformers

6.12.1 The requirements for protection of transformers are given in IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 10.4.4 and Pt 6, Ch 2,6.12 of the Rules for Ships, which are to be complied with where applicable.

6.13 Harmonic filters

6.13.1 The requirements for protection of transformers are given in Pt 6, Ch 2,6.13 of the Rules for Ships, which are to be complied with.

■ *Section 7*
Switchgear and control gear assemblies

7.1 General requirements

7.1.1 The general requirements for switchgear and control gear assemblies and their components are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 7 and Pt 6, Ch 2,7.1 of the Rules for Ships, which are to be complied with where applicable. Special consideration shall be given for voltages above 35 kV a.c. and 1,5 kV d.c., Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.1.2 Switchgear and control gear assemblies and their components are to comply with one of the following Standards amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 61439, *Low voltage switchgear and control gear assemblies*;
(b) IEC 62271-200, *High-voltage switchgear and control-gear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 62271-201, *High voltage switchgear and control gear – Part 201: AC insulation-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV*;
(d) IEC 60255, *Electrical Relays – Part 5: Insulation coordination for measuring relays and protection equipment – Requirements and tests*;
(e) IEC 62271-205, *High-voltage switchgear and control-gear – Part 205: Compact switchgear assemblies for rated voltages above 52 kV*;
(f) IEC 62271-203, *High-voltage switchgear and control-gear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52kV*;
(g) alternative relevant International or National Standards.

In addition, the requirements of this Section are to be complied with.

7.2 Busbars

7.2.1 The requirements for busbars and their connections are given in Pt 6, Ch 2,7.2 of the Rules for Ships, which are to be complied with where applicable.

7.3 Circuit-breakers

7.3.1 The requirements for circuit-breakers are given in Pt 6, Ch 2,7.3 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.3.2 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2, *Low voltage switchgear and Control gear – Part 2: Circuit-breakers*;
(b) IEC 62271-100, *High-voltage switchgear and control gear – Part 100: High-voltage alternating-current circuit-breakers*;
(c) IEC 62271-108, *High-voltage switchgear and control-gear – Part 108: High-voltage alternating current disconnecting circuit-breakers for rated voltages of 72,5 kV and above*.
(d) Alternative relevant International or National Standards.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.4 Contactors

7.4.1 The requirements for contactors are given in Pt 6, Ch 2,7.4 of the Rules for Ships, which are to be complied with where applicable.

7.5 Creepage and clearance distances

7.5.1 The requirements for creepage and clearance distances are given in Pt 6, Ch 2,7.5 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.5.2 For assemblies with a rated voltage of up to and including 1kV, the requirement of 7.5.1 may met by complying with IEC 60092-302, *Electrical installations in ships – Part 302: Low-voltage switchgear and controlgear assemblies*.

- Tables 2.7.1 and 2.7.2 in Pt 6, Ch 2,7.5 of the Rules of Ships indicate the minimum clearance and creepage distances normally allowed.
- For assemblies installed in spaces where the environmental conditions are in excess of pollution degree 3 (that is conductive pollution occurs or dry, non conductive pollution occurs which is expected to be conductive due to condensation) as defined in IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules; the clearance distances for non-verified assemblies are to be used*.
- A minimum creepage distance of 16 mm is permitted for assemblies verified in accordance with the requirements of IEC 61439-2, *Low-voltage switchgear and control-gear assemblies – Part 2: Power switchgear and controlgear assemblies*.
- An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by 1.3.3.

7.5.3 For assemblies with a rated voltage above 1kV, the requirement of Pt 6, Ch 2,7.5.1 of the Rules of Ships may be met by complying with IEC 60092-503, *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*.

- Tables 2.7.1 and 2.7.2 in Pt 6, Ch 2,7.5 of the Rules of Ships indicate the minimum clearance and creepage distances normally allowed.
- For main switchboards rated at above 1kV, a minimum clearance distance of 25 mm is required for busbars and other bare conductors.

An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by 1.3.3.

For voltage levels above 15 kV a.c., creepage distances are to comply with manufacturer's recommendations and alternative relevant International or National Standards.

7.5.4 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 2.7.1 in Pt 6, Ch 2,7.5 of the Rules for Ships. Suitable bushing is to be provided in way of connections to equipment, where necessary, to comply with IEC 60137, *Insulated bushings for alternating voltages above 1 000 V*.

7.6 Degree of protection

7.6.1 The requirements for the degree of protection are given in Pt 6, Ch 2,7.6 of the Rules for Ships, which are to be complied with where applicable.

7.7 Distribution boards

7.7.1 The requirements for the distribution boards are given in Pt 6, Ch 2,7.7 of the Rules for Ships, which are to be complied with where applicable.

7.8 Earthing of high-voltage switchboards

7.8.1 The requirements for earthing of high-voltage switchboards are given in Pt 6, Ch 2,7.8 of the Rules for Ships, which are to be complied with where applicable.

7.9 Fuses

7.9.1 The requirements for fuses are given in Pt 6, Ch 2,7.9 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.9.2 Fuses are to comply with one of the following Standards amended where necessary for ambient temperature:

(a) IEC 60269, *Low-voltage fuses*;
(b) IEC 60282-1, *High voltage fuses – Part 1: Current-limiting fuses*;
(c) IEC 60282-2, *High-voltage fuses – Part 2: Expulsion fuses*;
(d) Alternative relevant International or National Standards for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrails or handles

7.10.1 The requirements for handrails or handles are given in Pt 6, Ch 2,7.10 of the Rules for Ships, which are to be complied with where applicable.

7.11 Instruments for alternating current generators

7.11.1 The requirements for instruments of the alternating current generators are given in Pt 6, Ch 2,7.11 of the Rules for Ships, which are to be complied with where applicable.

7.12 Instrument scales

7.12.1 The requirements for instrument scales are given in Pt 6, Ch 2,7.12 of the Rules for Ships, which are to be complied with where applicable.

7.13 Labels

7.13.1 The requirements for labels are given in Pt 6, Ch 2,7.13 of the Rules for Ships, which are to be complied with where applicable.

7.14 Protection

7.14.1 The requirements for protection are given in Section 6, which are to be complied with.

7.15 Wiring

7.15.1 The requirements for wiring are given in Pt 6, Ch 2,7.15 of the Rules for Ships, which are to be complied with where applicable.

7.16 Position of switchboards

7.16.1 The requirements for position of switchboards are given in Pt 6, Ch 2,7.16 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.16.2 When switchboards and section boards contain withdrawable equipment, an unobstructed space as defined by the manufacturer but not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position. Adequate space for operation and maintenance is to be provided around and above the switchboards and section boards.

7.16.3 So far as possible, pipes should not be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see* Pt 5, Ch 13,2 of the Rules for Ships and Pt 5, Ch 13,2.

7.16.4 For switchgear and controlgear assemblies, for rated voltages above 1 kV a.c., arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* or Annex B of IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV* and qualified for classification IAC (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 The requirements for switchboard auxiliary power supplies are given in Pt 6, Ch 2,7.17 of the Rules for Ships, which are to be complied with where applicable.

7.18 Testing

7.18.1 The requirements for testing are given in Pt 6, Ch 2,7.18 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.18.2 For switchgear and control gear assemblies, for rated voltages above 1 kV a.c., type tests are to be carried out in accordance with Annex A of IEC 62271-200:2011, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* or Annex B of IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV* and IAC (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 The requirements for testing are given in Pt 6, Ch 2,7.19 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

7.19.2 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3, *Low voltage switchgear and control gear Part 3: switches, disconnectors, switch-disconnectors and fuse combination units*;

(b) IEC 62271-102, *High-voltage switchgear and control gear – Part 102: High-voltage alternating current disconnectors and earthing switches*;

(c) IEC 62271-104, *High-voltage switchgear and control gear – Part 104: Alternating current switches for rated voltages of 52 kv and above*;

(d) Alternative relevant International or National Standards.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ *Section 8*
Protection from electric arc hazards within electrical equipment

8.1 Hazard identification, calculations and testing

8.1.1 The requirements for protection from electric arc hazards within electrical equipment are given in Pt 6, Ch 2,8 of the Rules for Ships, which are to be complied with.

■ *Section 9*
Rotating machines

9.1 Construction, performance, control and testing

9.1.1 The requirements for construction, performance, control and testing of rotating machines are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 5 and Pt 6, Ch 2,9 of the Rules for Ships, which are to be complied with.

9.1.2 Additions or amendments to these requirements are given in 9.2.

9.2 Temperature rise

9.2.1 The limits of temperature rise specified in Table 2.9.1 in Pt 6, Ch 2,9.3 of the Rules for Ships are based on the cooling air temperature and cooling water temperature given in 1.9.2(a).

9.2.2 If it is known that the temperature of cooling medium exceeds the values given in 1.9.2(a) the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

9.2.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.9.2(a) the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.9.2(a), up to a maximum of 15°C.

■ *Section 10*
Converter equipment

10.1 Transformers

10.1.1 The requirements for transformers are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 6 and Pt 6, Ch 2,10.1 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

10.1.2 Transformers are to comply with the requirements of IEC Publications 60076, *Power transformers*, or alternative relevant International or National Standards amended where necessary for ambient temperature, *see* 1.9.

10.2 Semi-conductor converters

10.2.1 The requirements for semi-conductor converters are given in IEC 61892-3:2013, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 8 and Pt 6, Ch 2,10.2 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

10.2.2 Semi-conductor converters are to comply with the requirements of IEC 60146: *Semi-conductor Converters*, or alternative relevant International or National Standards amended where necessary for ambient temperature, *see* 1.9.

10.3 Uninterruptible power systems (UPS)

10.3.1 The requirements for uninterruptible power systems are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Sections 8 and 9, and Pt 6, Ch 2,10.3 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

10.3.2 UPS units are to comply with the requirements of IEC 62040, *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*, or alternative relevant International or National Standard amended where necessary for ambient temperature, *see* 1.9.

10.3.3 A.C. Uninterruptable Power Systems (UPSs) shall have isolated neutrals or TN-S, *see* 5.1.3.

10.3.4 An external bypass, that is hardwired and manually operated, is to be provided to the UPS system, to allow for isolation of the UPS for safety during maintenance and maintain continuity of load power. When the UPS is operating in either normal or by-pass mode it must be ensured that there are no multiple system earths.

■ *Section 11* Electrical cables and busbar trunking systems (busways)

11.1 General

11.1.1 The general requirements of electrical cables, optical fibre cables and busbar trunking systems (busways) are given in Pt 6, Ch 2,11.1 of the Rules for Ships and IEC 61892-4 (all parts), *Mobile and fixed offshore units – Electrical installations – Part 4: Cables*, which are to be complied with where applicable.

11.2 Testing

11.2.1 The requirements for testing are given in Pt 6, Ch 2,11.2 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.2.2 For cables with rated voltage above 30 kV a.c. guidance for requirements and test methods can be obtained from IEC 60840, *Power Cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – Test methods and requirements*.

11.3 Voltage rating

11.3.1 The requirements for voltage rating are given in Pt 6, Ch 2,11.3 of the Rules for Ships, which are to be complied with where applicable.

11.4 Operating temperature

11.4.1 The requirements for operating temperature are given in Pt 6, Ch 2,11.4 of the Rules for Ships, which are to be complied with where applicable.

11.5 Construction

11.5.1 The requirements for construction are given in Pt 6, Ch 2,11.5 of the Rules for Ships, which are to be complied with where applicable.

11.6 Conductor size

11.6.1 The requirements for conductor sizing are given in Pt 6, Ch 2,11.6 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.6.2 The cable current ratings given in Tables 2.11.3 and 2.11.4 in Pt 6, Ch 2,11.6 of the Rules for Ships are based on the maximum rated conductor temperatures given in Table 2.11.2 in Pt 6, Ch 2,11.4 of the Rules for Ships. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table 2.11.4, may be applied using the data provided in:

- IEC 60724, *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV)*; or
- IEC 60986, *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.
- IEC 61443, *Short-circuit temperature limits of electric cables with rated voltages above 30 kV (Um = 36 kV).*

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

11.7 Correction factor for cable current rating

11.7.1 The requirements for the correction factor for cable current rating are given in Pt 6, Ch 2,11.7 of the Rules for Ships, which are to be complied with where applicable.

11.8 Installation of cables

11.8.1 The requirements for installation of cables are given in Pt 6, Ch 2,11.8 of the Rules for Ships and IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation*, Section 5, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.8.2 The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 2.11.6 in Pt 6, Ch 2,11.8 of the Rules for Ships. Bends in fixed electric cable runs are only to be in accordance with the cable manufacturer's recommendations if the recommended bending radii are greater than the values given in Table 2.11.6 in Pt 6, Ch 2,11.8 of the Rules for Ships.

11.8.3 All cables as far as is practicable are to be located outside areas at risk of cryogenic spill.

11.9 Mechanical protection of cables

11.9.1 The requirements for mechanical protection of cables are given in Pt 6, Ch 2,11.9 of the Rules for Ships, which are to be complied with where applicable.

11.10 Cable support system

11.10.1 The requirements for the cable support system are given in Pt 6, Ch 2,11.10 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.10.2 The distances between the points at which the cable is supported (e.g., distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e., size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 2.11.7 in Pt 6, Ch 2,11.10 of the Rules for Ships or manufacturer's recommendations, whichever requires a smaller distance between supports.

11.11 Penetration of bulkheads and decks by cables

11.11.1 The requirements for penetrations of bulkheads and decks by cables are given in Pt 6, Ch 2,11.11 of the Rules for Ships, which are to be complied with where applicable.

11.12 Installation of electric and optical fibre cables in protective casings

11.12.1 The requirements for installation of electric and optical fibre cables in protective casings are given in Pt 6, Ch 2,11.12 of the Rules for Ships, which are to be complied with where applicable.

11.13 Non-metallic cable support systems, protective casings and fixings

11.13.1 The requirements for non-metallic cable support systems, protective casings and fixings are given in Pt 6, Ch 2,11.13 of the Rules for Ships, which are to be complied with where applicable.

11.14 Single-core electric cables for alternating current

11.14.1 The requirements for single-core electric cables for alternating current are given in Pt 6, Ch 2,11.14 of the Rules for Ships, which are to be complied with where applicable.

11.15 Electric cable ends

11.15.1 The requirements for electric cable ends are given in Pt 6, Ch 2,11.15 of the Rules for Ships, which are to be complied with where applicable.

11.16 Joint and branch circuits in cable systems

11.16.1 The requirements for joint and branch circuits in cable systems are given in Pt 6, Ch 2,11.16 of the Rules for Ships, which are to be complied with where applicable.

11.17 Busbar trunking systems (bustrunks)

11.17.1 The requirements for busbar trunking systems (bustrunks) are given in Pt 6, Ch 2,11.17 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

11.17.2 Where the busbar trunking system is employed for circuits on and below the freeboard deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.10 for essential electrical equipment.

■ *Section 12* Batteries

12.1 General

12.1.1 The requirements for batteries of the vented and valve regulated sealed type are given in IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 9 and Pt 6, Ch 2,12.1 of the Rules for Ships, which are to be complied with where applicable.

12.2 Construction

12.2.1 The requirements for construction are given in Pt 6, Ch 2,12.2 of the Rules for Ships, which are to be complied with where applicable.

12.3 Location

12.3.1 The requirements for construction are given in Pt 6, Ch 2,12.3 of the Rules for Ships, which are to be complied with where applicable.

12.4 Installation

12.4.1 The requirements for installation are given in Pt 6, Ch 2,12.4 of the Rules for Ships, which are to be complied with where applicable.

12.5 Ventilation

12.5.1 The requirements for ventilation are given in Pt 6, Ch 2,12.5 of the Rules for Ships, which are to be complied with where applicable.

12.6 Charging facilities

12.6.1 The requirements for charging facilities are given in Pt 6, Ch 2,12.6 of the Rules for Ships, which are to be complied with where applicable.

12.7 Recording of batteries for emergency and essential services

12.7.1 The requirements for recording batteries are given in Pt 6, Ch 2,12.7 of the Rules for Ships, which are to be complied with where applicable.

■ *Section 13* Equipment – Heating, lighting and accessories, electric trace heating and underwater systems

13.1 Heating and cooking equipment, lighting, socket outlets and plugs and enclosures

13.1.1 The requirements for heating and cooking equipment, lighting, socket outlets and plugs, and equipment enclosures are given in IEC 61892-3, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment* and Pt 6, Ch 2,13 of the Rules for Ships, which are to be complied with.

13.2 Electric trace heating

13.2.1 Electric trace heating shall comply with IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 12 trace heating installations in hazardous areas shall comply with IEC 60079, *Explosive atmospheres – Part 0: Equipment – General requirements* series or a relevant International or National Standard.

13.3 Underwater systems/impressed current cathodic protection

13.3.1 Underwater systems and appliances are to comply with IEC 61892-3:2012, *Mobile and fixed offshore units – Electrical installations – Part 3: Equipment*, Section 14. To facilitate diving operations provision is to be made to isolate Impressed Current Cathodic Protection Systems.

■ *Section 14* Refrigeration

14.1 General

14.1.1 Refrigeration required in units to facilitate LNG production and/or cryogenic storage is to comply with the requirements of IEC 60092-502, *Electrical installations in ships – Tankers – Special features*. Control and instrumentation associated with refrigeration systems is to comply with IEC 60092-504, *Electrical installation in ships – Special features – Control and Instrumentation*.

14.1.2 For LR approval of LNG refrigeration/reliquefaction system, the plant is to be considered as a self-contained essential system. Therefore, approval procedures will be performed for the complete plant as well as the major items of equipment.

14.1.3 Electrical, control and instrumentation equipment is to be suitable for its intended purpose and accordingly, whenever practicable, is to be selected from the *List of Type Products* published by LR. A copy of the procedure for LR Type Approval System will be supplied on application.

■ *Section 15* Navigation and manoeuvring systems

15.1 Steering gear

15.1.1 The requirements for steering gear are given in Pt 6, Ch 2,15.1 of the Rules for Ships, which are to be complied with. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

15.1.2 These requirements are to be read in conjunction with those in Pt 5, Ch 19.

15.1.3 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also* 3.7.9.

15.2 Thruster systems for steering

15.2.1 Where azimuth or rotatable thruster units, used as the sole means of steering, are electrically driven, the requirements of Pt 5, Ch 20,5 of the Rules for Ships are to be complied with.

15.3 Thruster systems for dynamic positioning

15.3.1 For units having a **DP** class notation the requirements of Pt 3, Ch 9 are to be complied with.

15.4 Thruster systems for manoeuvring

15.4.1 Where a thruster system is fitted solely for the purpose of manoeuvring and is electrically driven, the requirements of Pt 6, Ch 2,15.4 of the Rules for Ships are to be complied with.

15.5 Transverse thrust units

15.5.1 Where transverse units are remotely controlled, the requirements of Pt 6, Ch 2,15.5 of the Rules for Ships are to be complied with.

15.6 Thruster systems for thruster-assisted mooring systems

15.6.1 For units having a thruster-assisted positional mooring system the requirements of Pt 3, Ch 10 are to be complied with.

15.7 Navigation lights and sound signals

15.7.1 The requirements for navigation lights are given in IEC 61892-5:2010, *Mobile and fixed offshore units – Electrical installations – Part 5: Mobile units*, Section 7 and Pt 6, Ch 2,15.6 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

15.7.2 Navigation lights are to be connected separately to a distribution board reserved for this purpose only, and accessible to the Officer of the Watch. The distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with 3.2.4(b)(i) and 3.2.5(a). *See also* 3.7.9. An alarm is to be activated in the event of failure of a power supply from the distribution board. Disconnectable units are permitted for this purpose, i.e., for when the unit is not stationary and engaged in operations.

15.7.3 Signalling lights or sound signals required for marking offshore structures are to be fed from an emergency source of electrical power, *see* 3.2.4(e).

15.7.4 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also* 3.7.9.

15.8 Navigational aids

15.8.1 Navigational aids as required by SOLAS are to be fed from the emergency source of electrical power, *see also* Pt 6, Ch 2,3.3.7(d)(ii) of the Rules for Ships, which are to be complied with. Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also* 3.7.9. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

15.8.2 When a unit is stationary and engaged in operations, navigation aids (lanterns and sound signals) shall be provided in accordance with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) requirements and the requirements of the coastal state in whose territorial sea or on whose continental shelf the unit is operating.

15.9 Helideck and aircraft warning lights

15.9.1 Helideck perimeter lighting, helideck floodlights, aircraft warning lights, status (wave-off) lights and unit identification signage are to comply with UK Standard CAP 437, *Standards for Offshore Helicopter Landing Areas* or the requirements of the coastal state in whose territorial sea or on whose continental shelf the unit is operating.

15.9.2 Helideck perimeter lighting, helideck floodlights, aircraft warning lights and status lights are to be supplied by a UPS backed supply. The UPS autonomy is to be agreed with LR and the unit Owner and be in accordance with the requirements of any relevant Statutory Regulations of the National Administrations in the country of registration and area of operation.

15.9.3 Signalling lights or sound signals required for marking offshore structures are to be fed from an emergency source of electrical power, *see* 3.2.4.

15.9.4 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see also* 3.7.9.

■ *Section 16* Electric propulsion

16.1 General

16.1.1 The requirements for electric propulsion are given in Pt 6, Ch 2,16 of the Rules for Ships, which are to be complied with. This Section applies to disconnectable self-propelled units or units which use their thrusters to stay on-station or to move off-station (e.g., in adverse weather conditions). Thruster systems fitted for the purpose of manoeuvring or steering are to comply with Section 15.

■ *Section 17* Testing and trials

17.1 Testing

17.1.1 The requirements for testing are given in Pt 6, Ch 2,21.1 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

17.1.2 For equipment operating at voltages above 15 kV a.c. testing should be in accordance with relevant International or National Standards acceptable to LR and is to be based on approved test schedules.

NOTES

1. For high voltage cables up to 36 kV a.c., high voltage testing may be carried out in accordance with IEC 60502 (all parts), *Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV).*

2. For high voltage cables up to 69 kV a.c., high voltage testing may be carried out in accordance with IEEE Std. 400.2, *IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)*.

17.1.3 Minimum values of test voltage and insulation resistance are given in Table 2.17.1, as per IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation*, Section 17.3.

Table 2.17.1 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 400$	500	1
$400 < U_n \leq 500$	500	$\frac{U_n}{1000} + 1$
$500 < U_n \leq 1000$	1000	$\frac{U_n}{1000} + 1$
$1000 < U_n \leq 6000$	2500	$\frac{U_n}{1000} + 1$
$6000 < U$	5000	$\frac{U_n}{1000} + 1$

17.1.4 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed. It is to be ensured that the test voltage is above the operation voltage.

17.2 Trials

17.2.1 The requirements for trials are given in Pt 6, Ch 2,21.2 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

17.2.2 For equipment operating at voltages above 15 kV a.c. testing should be in accordance with relevant International or National Standards acceptable to LR and is to be based on approved test schedules.

17.2.3 Minimum values of test voltage and insulation resistance are given in Table 2.17.1, as per IEC 61892-6:2007, *Mobile and fixed offshore units – Electrical installations – Part 6: Installation*, Section 17.3.

17.3 High voltage cables

17.3.1 The requirements for high voltage cables are given in Pt 6, Ch 2,21.3 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

17.3.2 For equipment operating at voltages above 15 kV a.c. testing should be in accordance with relevant International or National Standards acceptable to LR.

17.4 Hazardous areas

17.4.1 The requirements for testing of electrical equipment located in hazardous areas are given in Pt 6, Ch 2,21.4 of the Rules for Ships, which are to be complied with where applicable.

NOTE
For hazardous areas, *see* Pt 7, Ch 2.

■ *Section 18* Spare gear

18.1 General

18.1.1 The general requirements for spare gear are given in Pt 6, Ch 2,22.1 of the Rules for Ships, which are to be complied with where applicable.

Section

A1 **Codes and standards**

Section A1 Codes and standards

A1.1 Abbreviations

A1.1.1 The following abbreviations are used in this Appendix:

CAP	Civil Aviation Publication
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

A1.2 Recognised Codes and Standards

A1.2.1 The following Codes and Standards are recognised by LR in connection with the design, construction and installation of equipment and systems which form part of the control and electrical systems installed on offshore units as appropriate.

A1.2.2 The following National and International Codes and Standards listed are subject to change/deletion without notice. The latest edition of a Code or Standard, with all applicable addenda, current at the date of contract award should be used.

A1.2.3 When requested, other National and International Codes and Standards may be used after special consideration and agreement by LR.

A1.2.4 Control and electrical systems:

CAP 437	Standards for Offshore Helicopter Landing Areas
IEC 60076	Power transformers
IEC 60079	Explosive atmospheres
IEC 60092-302	Electrical installations in ships — Part 302: Low-voltage switchgear and controlgear assemblies
IEC 60092-502	Electrical installations in ships — Part 502: Tankers — Special features
IEC 60092-503	Electrical installations in ships — Part 503: Special features — AC supply systems with voltages in the range of above 1 kV up to and including 15 kV
IEC 60092-504	Electrical installations in ships — Part 504: Special features — Control and instrumentation
IEC 60137	Insulated bushings for alternating voltages above 1 000 V
IEC 60146	Semiconductor converters — General requirements and line commutated converters
IEC 60255	Electrical Relays
IEC 60269	Low-voltage fuses
IEC 60282	High-voltage fuses
IEC 60502	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)
IEC 60724	Short-circuit temperature limits of electric cables with rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)
IEC 60840	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) — Test methods and requirements
IEC 60947	Low-voltage switchgear and controlgear
IEC 60986	Short-circuit temperature limits of electric cables with rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
IEC 61439	Low-voltage switchgear and controlgear assemblies
IEC 61443	Short-circuit temperature limits of electric cables with rated voltages above 30 kV (Um = 36 kV)
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61892	Mobile and fixed offshore units — Electrical installations
IEC 62040	Uninterruptible power systems (UPS)
IEC 62271-100	High-voltage switchgear and controlgear —Part 100: Alternating current circuit-breakers
IEC 62271-102	High-voltage switchgear and controlgear —Part 102: Alternating current disconnectors and earthing switches
IEC 62271-104	High-voltage switchgear and controlgear —Part 104: Alternating current switches for rated voltages of 52 kV and above
IEC 62271-108	High-voltage switchgear and controlgear — Part 108: High-voltage alternating current disconnecting circuit-breakers for rated voltages of 72,5 kV and above
IEC 62271-200	High-voltage switchgear and controlgear — Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
IEC 62271-201	High-voltage switchgear and controlgear —Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
IEC 62271-203	High-voltage switchgear and controlgear —Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV
IEC 62271-205	High-voltage switchgear and controlgear — Part 205: Compact switchgear assemblies for rated voltages above 52 kV
IEEE Std. 400.2	IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)

Rules and Regulations for the Classification of Offshore Units

Part 7
Safety Systems, Hazardous Areas and Fire

July 2014

Lloyd's Register

Chapter Contents

Contents

Part 7

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■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter applies to all units defined in Pt 1, Ch 2 on board which drilling, production and processing of hydrocarbons and/or storage of crude oil in bulk is undertaken. It is also applicable to Accommodation Units and Support Units as detailed in Pt 3, Ch 4. However, Accommodation Units and Support Units not engaged in activities with drilling, production and processing of hydrocarbons and/or storage of crude oil in bulk units need not comply with all the requirements of Section 2, in relation to gas detection, or the requirements of Sections 5, 6, 7 or 8 of this Chapter. This Chapter also states the fire detection requirements for units to be assigned the **UMS** and **CCS** notations, *see* Pt 6, Ch 1, Sections 4 and 5. Attention is to be given to the relevant Statutory Regulations of the National Administrations in the country of registration and area of operation, as applicable.

1.1.2 While Chapter 2 prescribes the boundaries of hazardous areas where special precautions are to be applied, the safeguards called for in this Chapter include provision for actions applicable where gas is present beyond hazardous area boundaries. Such circumstances may arise, for example, as the consequence of an uncontrolled well blow out or catastrophic failure of pipes or vessels.

1.1.3 These requirements apply to manned units. Special consideration will be given to unmanned units which are controlled from the shore or from another unit. When accommodation and support units are to operate for prolonged periods adjacent to live offshore hydrocarbon exploration or production units, it is the responsibility of the Owner/Operator to comply with the requirements of the appropriate National Administrations and special consideration will be given to the safety requirements for classification purposes, as appropriate.

1.1.4 Section 2 states general requirements for fire and gas detection systems. This Section also includes the additional fire detection requirements applicable for unattended machinery spaces and machinery spaces under continuous supervision from a centralised control station, *see* Pt 6, Ch 1,4.5 and 5.1.3, and incorporates requirements for accommodation units with spaces to house offshore personnel who are not members of the crew of the unit, *see* Pt 3, Ch 4.

1.1.5 Section 3 states requirements for personnel warning systems, general alarms and public address systems.

1.1.6 Section 4 states requirements for emergency lighting equipment.

1.1.7 Section 5 states the alarms and safeguards required for heating ventilation and air conditioning systems to protect against ingress of gas into safe areas, as defined in Chapter 2.

1.1.8 Section 6 states requirements which apply where ventilation systems are installed in enclosed and semi-enclosed hazardous areas, as defined in Pt 7, Ch 2,6.2.

1.1.9 Section 7 states requirements which apply to reduce fire and gas hazards in an emergency, by shutting down process plant and machinery.

1.1.10 Section 8 states requirements which apply to cargo transfer systems in an emergency, related to the release of the offloading configuration.

1.1.11 Section 9 states requirements for control and alarms of riser systems for the assignment of the special features class notation **PRS**.

1.1.12 Section 9 states requirements for the alarm and control of watertight closing appliances as required by Pt 4, Ch 7 and the requirements for the warning of ingress of water.

1.2 Documentation

1.2.1 The following documentation, as far as applicable to the unit, are to be submitted:

(a) For fire and gas systems:
- Fire and gas system design philosophy document.
- Fire and gas system design specification.
- Loss control or hazard analysis charts.
- Block diagram showing interface and power supply arrangements.

- Fire and gas system 'cause and effect' diagrams, including actions on heating, ventilating and air conditioning systems.
- Layout drawing showing the positions of fire and gas detector heads, manually operated call points, control panels and repeaters, cable routes, and fire zones.
- Details of the make and type numbers of all detector heads, manual call points and associated panels.
- Fire pump control, alarm, starting and inhibiting arrangements.
- For programmable electronic systems and networked systems, *see* Pt 6, Ch 1,1.2.5.

(b) For public address and general alarms, unit status indicators and emergency lighting:
- Communications philosophy document.
- Block diagrams showing interfaces and power supply arrangements.
- Single line diagrams.
- Unit layout drawings showing location of fire zones, cryogenic spill areas, equipment and cable routes.
- For programmable electronic systems and networked systems, *see also* Pt 6, Ch 1,1.2.5.

(c) For protection against gas and smoke in safe and hazardous areas:
- Layout drawing of drilling and/or process equipment and gas detectors.
- Ventilation system flow diagrams and gas detectors.

(d) For emergency lighting:
- Single line diagram.
- General arrangement plans showing the location of equipment and cable routes.

(e) For emergency shut-down (ESD) systems:
- ESD philosophy document.
- Safety analysis tables based on results of HAZOP studies/reports.
- Process Flow Diagrams (PFDs).
- ESD safety analysis function evaluation charts (cause and effect matrices).
- Performance standards and criteria of the safety critical system.
- Process and Instrument Diagrams (P&IDs).
- Utility Flow Diagrams (UFDs)
- Cause and Effect diagrams (C&Es).
- Safety integrity level categorisation study for the instrument protective system.
- Instrument protective system reliability and availability calculations report.
- Alarm and trip schedules.
- Block diagrams showing interfaces and power supply arrangements.
- Physical arrangement of control panel.
- Details of manual trips, resets and override facilities.
- Layout drawings showing positions of the ESD system control panel, subpanels and manual trips.
- Wellhead and riser valve hydraulic schematics and control panels.
- ESD valve pneumatic and/or hydraulic schematics.
- For programmable electronic systems and networked systems, *see also* Pt 6, Ch 1,1.2.5, 2.9, 2.11 and 2.12.

(f) For emergency release systems (ERS):
- Safety integrity level categorisation study for the instrument protective system.
- Alarm and trip schedules.
- Block diagram showing interfaces and power supply arrangements.
- Physical arrangements of control panel.
- ERS valve pneumatic and/or hydraulic schematics.

(g) For watertight doors and other electrically operated closing appliances:
- Single line diagram.
- General arrangement plans showing the location of equipment and cable routes.

1.3 Safety and communications equipment

1.3.1 Requirements for construction, detailed design, survey, inspection and testing of electrical and electronic equipment are contained in Pt 6, Ch 1 and 2 respectively.

1.3.2 Requirements for construction, detailed design, survey, inspection and testing of pneumatic and hydraulic equipment are contained in Pt 5, Ch 1, Ch 12 and Ch 14.

1.3.3 Equipment used in safety and communication systems should be suitable for its intended purpose, and accordingly, whenever practicable, should be selected from the *List of Type Approved Products* published by Lloyd's Register (LR). A copy of the *Procedure for LR Type Approval System* will be supplied on application. For fire detection alarm systems, *see* 2.2.9. For networked and programmable electronic systems, *see* Pt 6, Ch 1,1.25, 2.9 to 2.12.

1.3.4 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system, *see* Pt 6, Ch 1,1.3.5 and 3.13.12.

1.3.5 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard.

■ *Section 2* Fire and gas alarm indication and control systems

2.1 General requirements

2.1.1 This Section states general requirements for fire and gas detection alarm indication and control systems. *See also* Sections 5, 6 and 7 for requirements concerning protection against gas leakage and shut-downs for process systems and associated equipment.

NOTE
The requirements for the audible and visual presentation of alerts and indicators should be determined by reference to the IMO Code on Alerts and Indicators 2009.

2.2 Fire and gas detection alarm panels and sensors

2.2.1 The requirements for fire detection alarms panels and sensors are given in Pt 6, Ch 1,2.8 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). These Rules are also to be complied with where applicable for gas detection alarms panels and sensors and fire detection alarms panels and sensors specific to the unit's requirements. For units containing drilling facilities, specific reference should be made to the requirements of the 2009 IMO MODU Code Resolution A.1023(26) Ch 9, regarding fire and gas detection. For units with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities, *see* Pt 11, Ch 13,6.

2.2.2 Automatic fire and gas detection alarm panels and sensors that satisfy the requirements of 2.2.3 to 2.2.14 are to be fitted. Additional requirements for accommodation spaces and machinery spaces are given in 2.5 and 2.6.

2.2.3 A fire and gas detection indicating panel is to be located at the centralised control station. A repeater panel is to be provided at a location which is readily accessible to responsible members of the crew at all times, at the fire control station, if fitted, and at, or adjacent to, the work-station for navigation and manoeuvring or the workstation for safety, on the navigating bridge, if fitted. The main panel and the fire-control station repeater are to indicate the source of the fire in accordance with arranged fire zones by means of a visual signal. Any other repeater panel(s) should indicate the general area of the fire zones affected.

2.2.4 The activation of any detector or manually operated call point shall initiate a visual and audible fire and gas detection alarm signal at the alarm and repeater panels. If the signal(s) has not been acknowledged within 2 minutes, an audible fire and gas alarm, having a characteristic tone, distinguishable from any other alarm, is to be automatically and immediately audible in all parts of the navigating bridge, if fitted, the workstations for navigation and manoeuvring, the fire control station, if fitted, all accommodation areas (with the exception, on accommodation units, of those for offshore personnel), and machinery spaces. The alarm need not be an integral part of the detection system.

2.2.5 In addition to the areas required by the Rules for Ships, facilities are to be provided in the fire and gas detection system to initiate manually the alarm referred to in 2.2.4 from the following locations:

- Accommodation areas.
- The Unit Manager's office.
- Control stations in machinery and process areas.
- The main control station or fire-control station, if fitted.
- Throughout the installation in accordance with the defined fire and gas detection philosophy.

2.2.6 Fire and gas detection and alarm systems are to be provided with an emergency source of electrical power as required by Pt 6, Ch 2,3 and are also to be connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the main fire detection indicator panel, *see also* Pt 6, Ch 2,1.13 and 3.1.5. *See also* Pt 6, Ch 2,3.7.9. Reference should also be made to the guidance given in ISO 13702 to the supply capacity of UPS systems to defined emergency/critical facilities for the installation or unit. Failure of any power supply is to initiate an audible and visual alarm.

2.2.7 Fire and gas detectors are to be grouped as appropriate into zones conforming to passive fire protection boundaries and/or safe/hazardous area boundaries, as defined in Chapter 2. Further zones subdividing the above boundaries may also be arranged, where beneficial. Factors influencing zone boundaries include ventilation arrangements, bulkheads and the needs of the operating staff in locating and dealing with fire and gas incidents.

2.2.8 A zone/section of fire detectors which covers a control station, a service space or an accommodation space is not to include a machinery space or process area.

2.2.9 Fire and gas detection systems control and indicator panels, repeater panels, detectors heads, manual call points and short-circuit isolation units are to be suitable for their intended purpose. Detectors shall be certified by a recognised certifying authority for their intended purpose, where practicable, these should be selected from LR's *List of Type Approved Products*. Other bespoke design such as control panels, etc., (*see also* 2.6.3) should either be certified by a recognised certifying authority for its intended purpose (where practicable, these should be selected from LR's *List of Type Approved Products)* or the design appraised by Lloyd's Register.

2.2.10 The fire detection system, and any associated gas detection for the accommodation spaces, as required by 2.5, is to be integrated with, or suitably interfaced with, the main fire and gas detection control and indication panel. Similarly, any other permanent local fire and gas detection system is to be integrated with, or suitably interfaced with, the main fire and gas detection control and indication panel. Integrated systems should not result in reducing the integrity of the individual functions.

2.2.11 When it is intended that a particular loop or detector is to be temporarily switched off, reactivation need not be automatic after a preset time provided alternative acceptable means are in place to ensure re-activation has been successfully carried out.

2.2.12 Fire detector heads for the process and wellhead area, fusible plugs and linear electric elements for direct actuating of the deluge system may be used to supplement the automatic fire detection system.

2.2.13 Gas detectors are to be selected having regard to the flammable and/or toxic gases potentially present in each particular area or compartment and are to be sited having regard to the probable dispersal of the gas as governed by density, HVAC air flows and possible points of leakage, *see also* Sections 5 and 6.

2.2.14 Means are to be provided so that the sensitivity of gas detectors can be readily tested in their mounted positions by the injection of span gas or other equivalent method.

2.2.15 In addition to the fixed gas detection system, portable gas detectors of each of the following types, together with any necessary test facilities for checking their accuracy, are to be provided for all anticipated gas hazards including the following:

- Hydrocarbon gas detectors range 0 to 100 per cent of the lower explosive limit.
- Toxic gas detectors.
- Oxygen concentration meters.

2.3 Fire-extinguishing systems

2.3.1 The fire and gas detection system is to be arranged to initiate manually and automatically appropriate extinguishing system control actions, with the exception of asphyxiation gases such as carbon dioxide, *see* 2.3.3(a), by:

- actuating fire-fighting media and pre-release warnings;
- initiating fire and gas damper closures and stopping of ventilation fans to reduce the effect of fire and minimise ingress of gas;
- starting fire pumps.

The arrangements are to comply with 2.3.2 to 2.3.10.

2.3.2 The operational state of fire-extinguishing facilities, including smothering gas, deluge, foam equipment, and fire water systems, are to be displayed on the main control panel and the fire control point repeater panel, if fitted, as follows:

- Charges of gas available for use, indication of zones into which gas has been released, and reserve capacity in hand.
- Indication of zones in which water deluge has been initiated.
- Liquid level in main installation (i.e., deck foam system, etc.) foam concentrate tank(s) and status of foam concentrate pumps and valves.
- Availability of fire pumps, indication of running and standby sets and positions of associated valves.
- Operational state of sprinkler systems.

2.3.3 The provision of manual and automatic release facilities for extinguishing media are to be designed to afford optimum protection to the installation, while giving proper regard to the safety of personnel as follows:

(a) Generally, the release of asphyxiating gases such as carbon dioxide should only be initiated locally by manual means since it is necessary to ensure that the space to be dealt with has been evacuated.
(b) Deluge systems and extinguishing gases which can be released without introducing an unacceptable health risk should be capable of being manually released locally and remotely at the fire and gas indication and control panel and at the fire-control station, if fitted.
(c) Automatic release of a fire-fighting system (i.e., deluge system, etc.) can be initiated by voting fire detectors or individual fire detectors.

2.3.4 Fire pumps are to be provided with automatic and manual starting facilities on the fire and gas detection indication and control panel. Automatic starting is to be initiated by activation of fire detection heads, operation of any manual call points or reduction of pressure in the fire main. Controls which start the standby set in the event of starting or running failure of the duty set are to be provided. Safeguards required in the event of flammable gas being detected in the vicinity of the fire pump are detailed under 5.1.9. Manual starting facilities are to be provided adjacent to all fire pumps.

2.3.5 The design of extinguishing systems is to be in accordance with SOLAS Chapter II-2 Reg. 10, and IMO International Code for Fire Safety Systems (FSS). However, installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities are, in general, to comply with the requirements of Pt 11, Ch 11. For units containing drilling facilities, reference should be made to the requirements of the 2009 MODU Code Ch 9.

(a) When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units, *see also* Pt 6, Ch 2,3.1.5(b)(iv). *See also* Pt 6, Ch 2,3.7.9.
(b) The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire-resistant type, where they pass through other high fire risk areas.
(c) Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power. Exclusive circuits are to be used for the two units, *see also* Pt 6, Ch 2,3.1.5(b)(v). *See also* Pt 6, Ch 2,3.7.9.
(d) Each electrically driven carbon dioxide refrigeration unit is to be arranged for automatic operation in the event of loss of the alternative unit.

2.3.6 Fire and gas dampers and ventilation fans serving areas in which fire has been detected and confirmed by group voting are to be shut down automatically. Similar action is to be carried out prior to the release of extinguishing media. Manual shut-down from the main control panel and the fire control position is also to be available. The provision to close fire dampers manually from both sides of the bulkhead or deck, the integrity of which they are intended to maintain in line with the requirements of SOLAS and the MODU Code, should also be considered. To comply with those requirements, provision of means to close fire and gas dampers from a local position (such as, for instance, the space they serve) and a remote position (such as, for instance, the space where the fan is located) would be acceptable. Additionally:

(a) The electrical power required for the control and indication circuits of fire and gas dampers is to be supplied from the emergency source of electrical power. *See also* Pt 6, Ch 2,3.7.9.

(b) The control and indication systems for the fire and gas dampers are to be designed on the fail safe principle, with the release system having a manual reset.

2.3.7 The electrical power required for the control, indication and alarm circuits of fire doors is to be supplied from the emergency source of electrical power. *See also* Pt 6, Ch 2,3.7.9. The control and indication systems for the fire doors are to be designed on the fail safe principle, with the release system having a manual reset.

2.3.8 Automatic sprinkler systems are to be considered as part of the fire detection system.

2.3.9 Whenever any sprinkler comes into operation, an alarm and visual indication is to be initiated on the panels and repeaters required by 2.3.2.

2.3.10 The main fire and gas panel and the fire control point repeater, if fitted, are to indicate the location and zone/section of the sprinklers that have been initiated and the status of the system, as follows:

(a) Low level and pressure in the standing fresh water pressure tank.
(b) Start-up of the electrically driven pump which is brought into action automatically by the pressure drop in the system, before the standing fresh water charge in the pressure tank is completely exhausted.
(c) The status of the electrically driven or diesel-driven sea-water fire pumps, that are required to start up when the fresh water system is exhausted.

2.3.11 The design of sprinkler systems is to be in accordance with SOLAS Chapter II-2 Reg. 10, and IMO International Code for Fire Safety Systems (FSS) Ch 8. The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic changeover facilities located in, or adjacent to, the main alarm and detection panel.

2.4 Fire safety stops

2.4.1 Means of stopping all ventilating fans, with manual reset, are to be provided, outside the spaces being served, at positions which will not readily be cut off in the event of a fire. The provisions for machinery spaces are to be independent of those for other spaces.

2.4.2 Machines driving forced and induced draught fans, and independently driven pumps for lubricating, hydraulic or stored oil are to be fitted with remote controls, with manual reset, situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

2.4.3 Means of cutting off power to the galley, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

2.4.4 Fire safety stop systems are to be designed on the fail safe principle or, alternatively, the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see* Pt 6, Ch 2,10.5.3 of the Rules for Ships.

2.5 Additional requirements for accommodation fire detection systems

2.5.1 The requirements for accommodation fire detection systems are given in Pt 6, Ch 2,17.1 of the Rules for Ships, which are to be complied with where applicable.

2.5.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable as in 2.5.3 to 2.5.7.

2.5.3 Fire detection systems for crew accommodation spaces and accommodation spaces for offshore personnel as defined in Pt 1, Ch 2,2 of these Rules, and for accommodation and support units, are to comply with the additional requirements given below.

2.5.4 Where the fire detection system does not include means of remotely identifying each detector individually, a minimum of two zones/sections of detectors is to serve cabin spaces and they are to be arranged one on each side of the unit. Exceptionally, one zone/section of detectors may be permitted to serve both sides of the unit and more than one deck where it is satisfactorily shown that the protection of the unit against fire will not be reduced thereby.

2.5.5 Heat detectors used for the protection of accommodation spaces are to operate before the temperature exceeds 78°C, but not until the temperature exceeds 54°C.

2.5.6 The permissible temperature of operation of heat detectors may be increased by 30°C above the maximum deckhead temperature in drying rooms and other accommodation spaces having a normal high ambient temperature.

2.5.7 The maximum spacing of detectors in the living quarters is to be in accordance with Table 1.2.1. Other spacing complying with appropriate National Standards will be permitted.

Table 1.2.1 Maximum fire detector spacing

Type of detector	Maximum floor area per detector, in m^2	Maximum distance apart between centres, in metres	Maximum distance away from bulkheads, in metres
Heat	37	9	4,5
Smoke	74	11	5,5

2.6 Machinery space fire detection systems

2.6.1 Where an automatic fire detection system is to be fitted in a machinery space the requirements of 2.2 and the additional requirements of 2.6.2 to 2.6.5 are to be satisfied. These requirements are also to be applicable for units to be assigned the **UMS** and **CCS** notations, *see* Pt 6, Ch 1.

2.6.2 An audible fire alarm is to be provided having a characteristic tone which distinguishes it from other audible warnings having lower priority. The audible fire alarm is to be immediately audible at the main control station and at all repeater stations. If the alarm is not accepted within two minutes, a general alarm is to be initiated throughout the unit.

2.6.3 Fire detection control units, indicating panels, detectors, manual call points and short-circuit isolation units are to be Type Approved in accordance with *Test Specification Number 1* given in LR's *Type Approval System*. For addressable systems, which also require to be Type Approved, *see* Pt 6, Ch 1,2.9.

2.6.4 When it is intended that a particular loop is to be temporarily switched off locally, this state is to be clearly indicated at the main fire detection control panel. Such actions are to be controlled by a 'Permit-to-work' procedure.

2.6.5 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective.

■ *Section 3* Systems for broadcasting safety information

3.1 General

3.1.1 This Section states requirements for safety systems which broadcast warning of existing and potential hazards present on the unit and advise personnel on board of necessary actions they need to take.

NOTE

The requirements for the sound pressure levels to be provided by the public address system and audible alarms should be determined by reference to the International Life-Saving Appliances (LSA) Code and the IMO Code on Alerts and Indicators 2009.

3.2 Public address system

3.2.1 The requirements for public address systems are given in Pt 6, Ch 2,18.3 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

3.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable. In machinery spaces and other locations with high ambient noise levels, whether continuous or intermittent, audible alarms should be supplemented by visual alarms.

3.2.3 A public address (PA) system is to be provided which is to be audible in all parts of the unit. The PA microphones are to be located at the main control station and at the fire-control station and/or navigating bridge, if fitted. Additional microphones may be provided at other suitable locations, e.g., in the Unit Manager's office.

3.2.4 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see* Pt 6, Ch 2,3.7.9.

3.3 General emergency alarm systems

3.3.1 The requirements for general emergency alarm systems are given in Pt 6, Ch 2,18.2 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

3.3.2 A general alarm (GA) system is to be provided which is to be audible in all parts of the unit.

3.3.3 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see* Pt 6, Ch 2,3.7.9.

3.4 Fire-extinguishing media release alarms

3.4.1 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by Pt 6, Ch 2,3.1, and also connected to the main source of electrical power, with automatic changeover facilities located in or adjacent to the fire-extinguishing medium release panel. Failure of any power supply is to operate an audible and visual alarm, *see also* Pt 6, Ch 2,1.14 and Pt 6, Ch 2,3.7.9.

3.5 Escape route or low location lighting (LLL)

3.5.1 Escape route or low level location lighting (LLL), in the form of either electrically powered systems or photo-luminescent strip indicators, is to be provided in accordance with the requirements of Chapter II-2, Regulation 13.3.2.5.1. Where electrically powered systems are used the arrangements are to comply with the requirements of this sub-Section.

3.5.2 Where an electrically powered system is used, the LLL system is to be provided with an emergency source of electrical power as required by Pt 6, Ch 2,3.1 and also connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel. *See also* Pt 6, Ch 2,3.7.9. For Accommodation Units the LLL system is to be provided with an emergency source of electrical power as required by Pt 3, Ch 4,4.2 and also connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel. The system is to be capable of being operated under fire conditions, *see also* IEC 61892-2:2012, *Mobile and fixed offshore units – Electrical installations – Part 2: System design*, Section 12.12.2.4 and Pt 6, Ch 2,1.16 of the Rules for Ships.

3.5.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire, in any one fire zone or deck, does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with Pt 6, Ch 2,10.5.3 of the Rules for Ships, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL, for a minimum period of 60 minutes. If the accommodation or part of the accommodation is classified as the Temporary Refuge, the LLL integral batteries are to have a minimum supply capacity of 60 minutes or a period in excess of 60 minutes if the Temporary Refuge is to be rated to maintain integrity for a period in excess of 60 minutes. Where these units are installed within cabins for crew or offshore personnel, or within associated corridors, the batteries are to be of the sealed type, *see* Pt 6, Ch 2,11.2.

3.5.4 The performance and installation of lights and lighting assemblies are to comply with ISO 15370: *Ships and marine technology – Low location lighting on passenger ships – Arrangement*.

■ *Section 4*
Emergency lighting

4.1 General requirements

4.1.1 The requirements for emergency lighting are given in Pt 6, Ch 2,18.1 of the Rules for Ships, which are to be complied with where applicable. Additions or amendments to these requirements are given in the following paragraph(s) of this sub-Section.

4.1.2 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, *see* Pt 6, Ch 2,3.7.9.

■ *Section 5*
Protection against gas ingress into safe areas

5.1 General

5.1.1 Heating ventilation and air conditioning systems serving safe areas are to be provided with alarms and safeguards required by 5.1.2 to 5.1.9, to protect against hazards created by the ingress of gas.

5.1.2 Gas detectors are to be provided in or close to all air intakes serving safe areas. They are to be capable of initiating early warning of the presence of flammable and toxic gases likely to be present on the unit, as appropriate to its purpose or service. The detectors are also to be capable of initiating relevant shut-down actions, should the concentration of gas increase above the early warning level. To minimise nuisance shut-downs, consideration should be given to the provision of duplicated or triple redundant detector heads in each inlet operating in a voting configuration.

5.1.3 In addition to the detectors required by 5.1.2, for exhaust outlets of accommodation modules adjacent to gas hazardous areas, consideration should be given to provide gas detectors to give warning of ingress of gas when the ventilation system is shut down.

5.1.4 Automatically closed dampers are to be provided in all intakes and exhausts. When the gas detectors required by 5.1.2 and, if fitted, those to which 5.1.3 refers, have detected gas demanding shut-down action, all HVAC inlet and exhaust fans and dampers associated with the space/point where ingress of gas has been detected are to be shut down and closed in addition to the damper of the duct in which gas has been detected. No reliance is to be placed on solely shutting dampers without also shutting down the associated fan motors. Dampers utilised to mitigate against the ingress of gas are to be suitably rated for this service.

5.1.5 A five second retention time between air inlet gas detectors and downstream dampers is to be considered in the ducting design for machinery space ventilation. Where it can be shown that may not be practicable, lower retention times can be considered, subject to the following:

- all machinery and electrical equipment, if any, fitted in the ducting being of a type suitable for Hazardous area location as applicable , *see* Ch. 2, Section 5 and 8;
- early closure of dampers being initiated upon activation of gas detection system(s) in the process area, where applicable;
- hydrocarbon concentration within the ducting being the subject of a dispersion analysis, to allow assessment of hazards created, if any, to the machinery space being ventilated.

5.1.6 Where a machinery space is not served by redundant air intake ducts, consideration should be given to the provision of gas detection within the space. Consideration should also be given to the isolation of electrical equipment, other than that suitable for installation within a Zone 1 location, *see* Ch 2,8.1.4, when flammable gas is detected within the space.

5.1.7 The alarms for loss of ventilation and loss of over-pressure required by Ch 2,4 may be incorporated into the fire and gas central panel.

5.1.8 Consideration is to be given to the provision of gas detection within emergency generator spaces and their switchboard spaces as well as in the ventilation system intakes. In the event of gas being detected in the air intakes, the ventilation system intake and exhaust fan dampers are to be shut down and associated fan motors are to be stopped. The emergency generator may continue to run, provided that aspiration air is drawn separately from outside the space and the engine induction and exhaust arrangements comply with the relevant requirements of Ch 2,7. However, if gas is detected within the emergency generator enclosure, emergency switchroom, or at the engine air intake, the emergency generator is to be shut down.

5.1.9 Diesel-driven fire pumps will not require to be shut down if gas is detected in the area or space in which they are sited, provided that no electrical equipment, other than that suitable for installation in a Zone 1 location, *see* Ch 2,8.1.4, is required to remain in operation. Should any equipment not be suitable for such installation (firewater pump drives, i.e., diesel drive units, etc., are often not certified and are therefore not rated to operate in a hazardous atmosphere), they are to be suitably protected by other means (i.e., housed in a safe area, within a suitably rated enclosure with fire rated and gastight barriers, designed to run with the firewater pump drive enclosure shut down (i.e., enclosure fire and gas dampers closed, etc.), diesel drives provided with engine overspeed protection, etc.) to mitigate against gas ingress and enable the drive to continue to operate. Additionally, such pumps should not be started up with gas present, and any electrical starting circuits and control and alarm circuits not suitable for operation in a Zone 1 location are also to be isolated automatically by the fire and gas panel.

5.1.10 Ventilation systems serving Hazardous areas are to be fully segregated from ventilation systems serving Non-Hazardous areas.

5.1.11 Drain systems serving Hazardous areas are to be fully segregated from drain systems serving Non-Hazardous areas.

■ *Section 6* Protection against gas escape in enclosed and semi-enclosed hazardous areas

6.1 General

6.1.1 Enclosed and semi-enclosed hazardous areas as defined in Ch 2,1.2 are to be provided with alarms and safe guards required by 6.1.2 to 6.1.4 to give protection against accidental release of hydrocarbon and toxic gases.

6.1.2 Appropriate gas detectors are to be provided, to give warning of gas release in the following locations:

- Drill floor.
- Mudrooms.
- Shale shaker space.
- Wellhead and riser areas.
- Adjacent to process equipment.
- Machinery rooms with gas-fuelled equipment.
- Turret area.
- Any other location where there is a significant risk of a leakage of gas or of liquid liable to release flammable vapour.

6.1.3 Detectors are to be capable of initiating early warning of the presence of gas and are also to be capable of initiating relevant shut-down actions via the emergency shut-down system called for in Section 7 when higher gas concentrations are detected. To minimise nuisance shut-downs consideration should be given to trips initiated by confirmed response by more than one detector within the space concerned or the provision of similar voting arrangements.

6.1.4 Gas turbines and their enclosures are to be fitted with flammable gas detectors at the following locations:

- Turbine air intakes.
- Ventilation system air intakes.
- Ventilation system exhausts.

The presence of gas in the turbine air intake and/or ventilation system air intake is to initiate shut-down of the turbine and the ventilation system. If gas is sensed only in the ventilation exhaust, the ventilation system is to continue running and the turbine is to be shut down. Proposals involving shutting down and inerting the turbine machinery enclosure for the conditions described will be given special consideration.

6.1.5 If an enclosed hazardous area is supplied with a ventilation system, the presence of gas in the enclosed hazardous area and/or the ventilation system air extracts from this area is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area. However, other suitable shut-down functionality (i.e., tripping of electrical equipment within the area, process plant shut-down and emergency depressurisation, etc.) are to be initiated dependent upon the degree of hazard.

■ *Section 7* Emergency shutdown (ESD) systems

7.1 General

7.1.1 An emergency shutdown (ESD) system represents a layer of protection that mitigates and attempts to prevent a hazardous situation from occurring. An ESD system is to be provided when any process presents a hazard which could affect the safety of personnel, the overall safety of the unit or the pollution of the environment. Guidance on identifying hazards and assessing risk is provided in

ISO 17776, *Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment*. The system is to satisfy the requirements of this sub-Section.

7.1.2 The ESD system is to operate in association with process plant and safety critical facilities to incorporate levels of hierarchical shutdown appropriate to the degree of hazard to personnel, the unit and the environment. The arrangements are to be derived using hazard analysis techniques. Where the unit is to be connected to another installation, such as shore, vessel, other unit, etc., linked ESD systems should be provided and be capable of transmitting ESD signals to any of the connected installations and vice versa, *see* 7.4.

7.1.3 The operation of the ESD system is to be initiated manually. In addition, operation is also to be initiated automatically by signals derived from the fire and gas and cryogenic spill detection systems as well as signals derived from process and other equipment sensors. Drilling equipment is to be shut down automatically in a controlled manner upon activation of a high level or drilling ESD. ESD system is also to be activated upon loss of instrument air.

NOTE
Guidance on manual and automatic inputs is given in Pt 11, Ch 18,10.1.3 and Ch 18,.10.1.4.

7.1.4 ESD initiation is to activate audible and visual alarms in the central control room (CCR) and at strategic locations outside the CCR. The activation of a manual ESD activation point is to initiate the general alarm of the unit.

7.1.5 An ESD system shall continuously provide adequate information at a central control station allowing personnel involved in managing an emergency to have necessary information. ESD system status shall be continuously monitored in the central control room (CCR). Items to be considered for monitoring are the following:

- ESD level initiation.
- ESD effects which have failed to be executed upon ESD activation.
- Failure of ESD system component.

7.1.6 ESD functions shall as far as practicable be functionally and physically independent from other systems/ functions.

7.1.7 Manual ESD activation points for complete shutdown of the installations are to be provided at the central control room (CCR) and other suitable locations, e.g., at the helicopter deck and the emergency evacuation stations. Each manual ESD activation point on the installation is to be clearly identified. Manual ESD activation points are to be protected against inadvertent operation.

7.1.8 The ESD system is to be arranged with automatic changeover to a stand-by power supply, ensuring uninterrupted operation of the system, in the event of failure of the normal power supply.

7.1.9 Failure of any power supply to the ESD system is to operate an audible and visual alarm.

7.1.10 The stand-by power supply required by 7.1.8 should be capable of supplying power for ESD functions for a minimum duration of 30 minutes.

7.1.11 Upon failure of protective system, logic solvers, sensors, actuators or power source, the operation of the plant and equipment is to revert automatically to the least hazardous condition.

NOTE
This requirement is normally realised by employing a fail safe design. Special consideration is given to subsea christmas tree solenoid valves, which are not normally energised. Part of these special considerations for subsea tree valves is typically to provide high integrity solenoid valves which de-energise via the ESD system and vent the hydraulic fluid from the subsea christmas tree actuators to the topsides hydraulic skid. This process will eventually close the subsea tree valve via loss of hydraulic pressure.

7.1.12 Hydrocarbon related components are to be equipped with primary and secondary protection as defined in ISO 10418:2003, *Petroleum and natural gas industries – Offshore production installations – Analysis, design, installation and testing of basic surface process safety systems*, Section B.2 or alternative relevant International or National Standard, to prevent or minimise the effects of an equipment failure within the process. Where provision of two means of protection cannot be achieved, special consideration must be given to the design of the alternative means.

7.1.13 High level ESD (as defined in accordance with 7.1.2, e.g., platform shut-down, production shut-down) should only be provided with a capability to reset each final element locally. Elements affected by low level ESD (as defined in accordance with 7.1.2, e.g., equipment or component shutdown) may be reset by means of a remote manual group reset operation from the central control room.

NOTE
High level ESD is typically related to total platform shut-down, platform evacuation, etc.
Low level ESD is typically classified as a process train trip, single package trip, etc.

7.1.14 Maintenance override facilities shall only be provided for ESD sensors where a secondary form of protection for stopping the process is available to the operator, and the operator has sufficient time to respond to the event. Maintenance overrides shall not be provided for manual ESD inputs (i.e., ESD pushbuttons). Consideration should be given to the number of inhibits applied at any one time to an ESD system, to ensure that the ESD function is not impaired. Physical key switches are to be used for applying overrides to high level, safety-critical shut-down system inputs. The amount of time that the key switch is enabled shall be timed and alarmed if the allowable time is exceeded.

7.1.15 Start-up overrides may be applicable to low level and similar trips during plant start-up. These overrides are to be cancelled automatically once the normal process condition has been reached or when a fixed period of time has expired.

7.1.16 Where arrangements are provided for overriding parts of an ESD system, they should be such that inadvertent operation is prevented. When an override is operated, visual indication is to be given at the central control room.

7.1.17 Upon activation of the ESD system there shall be no means of overriding/resetting the system until such time as the conditions that triggered the system are returned to a safe state.

7.1.18 Accumulators for pneumatic and hydraulic systems are to have sufficient capacity to allow the performance of one complete shutdown followed by reset and a further shutdown without the need for recharging the accumulator. Accumulator pre-alarms will also be fitted and signals should have suitable time delays.

7.1.19 Manual valves which are part of the safety control circuits shall be secured in the correct position to ensure no inadvertent operation.

7.1.20 All emergency shut-down and blow down valves shall be fitted with open and closed position limit switches and indicators. Valve position shall be indicated in the central control room (CCR) and locally.

7.1.21 Where ESD applications are to be implemented by programmable electronic systems, a risk-based approach, as described in IEC 61508-5, *Functional safety of electrical/electronic/programmable electronic safety related systems – Part 5: Examples of methods for the determination of safety integrity levels* or alternative relevant International or National Standard, for the specification and design of these systems is to be adopted. The ESD system is to comply with the requirements of IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems* or alternative relevant International or National Standard and, as far as applicable, those of IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*. Each measure to control or mitigate hazards is to be assigned an appropriate degree of risk reduction which contributes to the overall risk reduction. The risk reduction figure is to be translated into performance standards for each measure which will be specified in terms of functionality, availability, reliability, survivability and interactions (FARSI), *see also* Pt 6, Ch 1,2.13.

7.1.22 The implementation of a programmable electronic system to perform high safety integrity level functions or any other form of logic solver (i.e., relay/solid state magnetic core) is to be via a suitable certified Safety Integrity Level (SIL) system, acceptable to LR, which will give an appropriate SIL for all SIL classified functions associated with the ESD system. This certification is to include calculations for Probability of Failure on Demand (PFD_{AVG}), architectural constraints in terms of safe failure fraction (SFF) and hardware fault tolerance (HFT), random failures as specified in IEC 61508-2:2010, *Functional safety of electrical/electronic/programmable electronic safety related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems*, Section 7.4.2.2 or alternative relevant International or National Standard.

7.1.23 ESD control units are, where practicable, to be Type Approved in accordance with *Test Specification Number 1* given in LR's *Type Approval System* for an environmental category appropriate for the locations in which they are intended to operate.

7.1.24 Status, diagnostic and alarm information exchange executed by read-only soft links to remote digital systems for display purposes may be provided, as applicable, by the Integrated Control and Safety System (ICSS) or matrix panels, *see* Pt 6, Ch 1,2.13.9 of the Rules for Ships.

7.1.25 Access to the system is to be restricted so that software may only be modified by suitably authorised personnel.

7.1.26 Consideration is to be given to the segregation of cabling and wiring associated with ESD functions from that associated with power cables.

7.1.27 All ESD equipment that is critical to provide an effective shut-down shall be protected against mechanical/environmental damage until the intended shut-down sequence is completed.

7.2 Electrical equipment

7.2.1 In addition to the requirements of 7.1, any electrical equipment which has to remain operational in a Major Accident Event (e.g., rupture of a process vessel or pipe) and is therefore capable of being subjected to a flammable atmosphere is to be of a type suitable for installation in a Zone 1 location, *see* Ch 2,8.1.6.

7.2.2 Electrical equipment which, on drilling units, is required to function following an emergency shut-down and provide continued operation during an ongoing emergency should be selected in accordance with the requirements of IMO MODU Code 2009 and IEC 61892-7, *Mobile and fixed offshore units – Electrical installations – Part 7: Hazardous areas*. Such equipment should be suitable for its intended application and be suitable for installation in Zone 1 locations; however, consideration will be given to alternative arrangements where they are shown to provide an equivalent level of safety to the satisfaction of LR.

Note

A Major Accident Event is defined in the Offshore Installations (Safety Case) Regulations 2005 (SI 2005/3117) as:

(a) A fire, explosion or release of a dangerous substance involving death or serious personal injury to persons on the installation or engaged in an activity on or in connection with it;
(b) Any event involving major damage to the structure of the installation or plant affixed thereto or any loss in the stability of the installation;
(c) The collision of a helicopter with the installation;
(d) The failure of life support systems for diving operations in connection with the installation, the detachment of a diving bell used for such operations or the trapping of a diver in a diving bell or other subsea chamber used for such operations; or
(e) Any other event arising from a work activity resulting in death or serious personal injury to five or more persons on the installation or engaged in an activity in connection with it.

7.3 Testing

7.3.1 Facilities are to be available for testing of both input/output devices and internal functions of the ESD system.

7.3.2 Factory Acceptance Test (FAT) is required for logic solvers implementing safety instrumented functions. A FAT is to be conducted in accordance with IEC 61511-1:2003, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements*, Section 13 or alternative relevant International or National Standard.

7.3.3 Function tests are to be conducted in accordance with Pt 6, Ch 1,7.1 where applicable, ISO 10418:2003, *Petroleum and natural gas industries – Offshore production installations – Analysis, design, installation and testing of basic surface process safety systems*, Annex G, or alternative relevant International or National Standard.

7.4 Linked ESD systems

7.4.1 A linked ESD system communicates ESD signals from unit to shore/vessel and vice versa, via a compatible interface.

7.4.2 A linked emergency shut-down (ESD) shall initiate a controlled cargo transfer process shut-down.

7.4.3 All relevant initiation signals at either end of the link shall be processed and transmitted through an established ESD link, as a single ESD signal and not as individual signals.

7.4.4 An independent back-up system shall be provided so that a common failure mode is reduced as far as is reasonably practicable.

7.4.5 Due consideration should be afforded to the sequence and timing of closure of ESD valves on both units, in order to mitigate for the hydraulic surge in the transfer lines.

7.4.6 A high-level functional flowchart of the linked ESD and related systems should be provided in the central control room (CCR).

7.4.7 The use of electric links should be reviewed to ensure protection against ignition during accidental cable damage and connect/disconnect operations.

7.4.8 Where an electrical ESD link is used, a standardised pin configuration should be adopted, as per ISO 28460:2010, *Petroleum and natural gas industries – Installation and equipment for liquefied natural gas – Ship-to-shore interface and port operations*, Section 14.4 or alternative relevant International or National Standard. Consideration will be given to use of other pin configurations.

7.4.9 Should additional information, such as telephone links, data for mooring tension monitoring systems, etc., be transferred through the linked ESD system, provision is to be made to ensure that these additional features do not interfere with the primary function of the linked ESD system.

7.4.10 Where additional services are supplied from shore, such as onshore power supply, these must be considered as part of the ESD safety analysis function evaluation charts, *see* 1.2.1(e).

7.4.11 Upon failure of ESD link between a non-manned installation and its remote control centre, there shall be an alternative facility to shut down the non-manned installation automatically.

■ *Section 8*
Emergency release systems (ERS)

8.1 General

8.1.1 Where the cargo transfer system between two units is fitted with a linked emergency shut-down (ESD) system, *see* 7.4, and an emergency release system (ERS), ensuring the coordinated operation of both ESD and ERS functions and the prevention of overpressure in the transfer system, the requirements of this Section are to be complied with. The design of ERS systems is to comply with the requirements of EN1474-1 and 3, *Installation and equipment for liquefied natural gas – Design and testing of marine transfer systems* or alternative relevant International or National Standard and this sub-Section.

8.1.2 The function of the ERS protects the offloading configurations by disconnecting them, should the units drift out of their operating envelope.

NOTES

1. Examples of offloading configurations are the following:
   - Marine transfer arms systems.
   - Rigid supported hose systems.
   - Aerial flexible hoses.
   - Floating flexible hoses.
2. Operating envelope is the maximum spatial area in which the presentation flange of an offloading configuration system can operate safely.

8.1.3 Means are to be provided to activate the Emergency Release System (ERS) manually from the central control station and locally, where the cargo transfer process is monitored or visually observed. Should the marine transfer arm/hose extend outside its operational envelope, this is to be detected by sensors, leading to automatic activation of the emergency release system (ERS).

8.1.4 Manual ERS activation points are to be protected against inadvertent operation.

8.1.5 In an emergency, when the offloading configuration requires to be disconnected, this should occur as a two-stage process:

- First stage: deployment of the linked ESD system, *see* Pt 7, Ch 1,7.4.
- Second stage: activation of the Emergency Release System (ERS), *see* 8.1.6.

The design of the systems should be such that the second stage cannot be activated unless the functions of the first stage have commenced.

8.1.6 The ERS activation sequence is as follows:

- simultaneous closure of the interlocking ERS isolating valves;
- activation of the Emergency Release Coupler (ERC);
- disconnection of the arms/hoses;
- retraction to safe position.

Each stage in the sequence must be complete before the next commences.

8.1.7 ERS activation procedures are to be clearly posted at the ERS operating location(s).

8.1.8 The emergency release system (ERS) is to be independent and separate from the linked ESD system. Although the ERS system is to be independent from the ESD system, it may share a common power source, provided that a failure in either system does not render the other system inoperable, e.g., failure in hydraulic or pneumatic control lines.

8.1.9 All relevant initiation signals at either end of the link shall be processed and transmitted through an established ERS link, as a single ERS signal and not as individual signals.

8.1.10 The overall design of the offloading configuration, ESD and ERS systems should consider offloading environmental conditions and locations. The design of this system shall take into account possible ice build-up.

8.1.11 The ERS operating system shall be designed to retain sufficient stored energy to release all transfer arms/hoses in the event of unit blackout and the non-availability of provided utilities. Loss of power should not result in automatic activation of the ERS.

8.1.12 An uninterruptible power supply is to be provided to supply power to the logic and control systems.

8.1.13 Electrical, electronic and programmable components which are part of the safety system shall comply with IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety related systems*.

8.1.14 Access to the system is to be restricted so that software may only be modified by suitably authorised personnel.

8.2 Electrical

8.2.1 In addition to the requirements of 8.1, any electrical equipment which has to remain operational in a Major Accident Event (e.g., rupture of a process vessel or pipe) and is therefore capable of being subjected to a flammable atmosphere is to be of a type suitable for installation in a Zone 1 location, *see* Pt 7, Ch 2,8.1.6.

8.2.2 Electrical isolation between units must be maintained during cargo transfers and connection/disconnection operations.

8.2.3 Each offloading configuration should have an electrical isolation arrangement installed at one of its connection flanges, to isolate electrically ship from the transfer arm/hose. The electrical resistance of the isolating flange is to be between 1 kΩ and 100 MΩ.

8.3 Testing

8.3.1 Factory Acceptance Test (FAT) is required for logic solvers implementing safety instrumented functions. A FAT is to be conducted in accordance to IEC 61511-1, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements*, Section 13 or alternative relevant International or National Standard. Factory Acceptance Tests are to satisfy the requirements of EN1474-1:2008, *Installation and equipment for liquefied natural gas – Design and testing of marine transfer systems Part 1: Design and testing of transfer arms*, Section 8.4 or alternative relevant International or National Standard.

8.3.2 Function tests are to be conducted in accordance with Pt 6, Ch 1,7.1 where applicable, ISO 10418:2003, *Petroleum and natural gas industries – Offshore production installations – Analysis, design, installation and testing of basic surface process safety systems*, Annex G, or alternative relevant International or National Standard.

■ *Section 9* Riser systems

9.1 General

9.1.1 The provisions laid down in Pt 3, Ch 5 for the assignment of the special features class notation **PRS** are to be complied with.

9.1.2 The location where the riser(s) is situated, inboard of the installation or unit, is to be safeguarded by an appropriate fire and gas detection system complying with the requirements of Section 2. In the event that a fire or confirmed gas leakage is detected, effective automatic means of closing down the riser(s) are to be provided.

9.1.3 The riser system is to be equipped with an emergency shut-down valve, fitted as close to the waterline as possible, but above the splash zone. The valve is to be of the self-actuating type with its own localised control medium and interfaces with the installation ESD, as specified in Section 7.

9.1.4 Testing facilities which actuate the inboard riser valves are to be provided, and initiated periodically to ensure actuator breakout forces are achieved.

9.1.5 The riser system is to be provided with means of leakage monitoring and to ensure integrity of the riser system (Trunk and Infield Pipelines, as applicable). The leak detection system should take the following parameters into consideration:

- Continuous mass balance (fiscal).
- Continuous volumetric balance corrected for

temperature and pressure (fiscal).
- Continuous monitoring of rate of change of pressure.
- Continuous monitoring of rate of change of flow.
- Low pressure alarm or trip.
- High flow alarms.

The leak detection system on **Infield Lines** should take the following parameters into consideration where relevant:
- Subsea choke position.
- Multiphase subsea flowmeter.
- Infield metering (when installed).
- Continuous monitoring of rate of change of pressure.
- Continuous monitoring of rate of change of flow.
- Low pressure alarm or trip.
- High flow alarm.

9.1.6 Control of the riser system is to be effected from a clearly defined control centre, provided with sufficient instrumentation to indicate the conditions at each end of the riser system and to ensure effective control, shut-down and disconnection.

9.1.7 Where more than one control centre is provided, the arrangements are to be such that only one control centre can start up the riser system at a given time. Clear indication is to be provided to show which centre is in control.

9.1.8 Independent means of voice communication are to be provided between the single point mooring end of the riser system and the control centre(s).

9.1.9 Alarms displayed in a control centre are to be audible and visual. An alarm event recorder is to be provided.

9.1.10 The riser system is required to be safely disconnected when the design limits are exceeded. Self-closing devices positioned as close to the rapid disconnecting point as possible are to be fitted so as to ensure accidental spillage at the junction is minimised. A suitable alarm is to be provided, warning that the design limits are reached.

■ *Section 10*
Protection against flooding

10.1 General requirements

10.1.1 The requirements for watertight and weathertight integrity and the general requirements regarding the control and closure of watertight and weathertight doors and hatch covers in order to satisfy the intact and damaged stability criteria are given in Pt 4, Ch 1 and Ch 8, to which reference should be made.

10.1.2 A system of alarm displays and controls is to be provided which will ensure satisfactory supervision and control of watertight doors and hatch covers, and also in the case of column-stabilised units to give warning of ingress of water.

10.1.3 For column-stabilised units, the alarm displays and controls are to be provided at a centralised panel at the ballast control station, *see* Pt 4, Ch 7,3, Pt 5, Ch 13,8.6 and Pt 6, Ch 1,2.8.

10.1.4 For ship and self-elevating units, the alarm displays and controls are to be provided at a centralised panel either at the ballast control station, the main control station, the workstation for navigation and manoeuvring or the workstation for safety, on the navigating bridge, as applicable, *see* Pt 4, Ch 8,3.

10.1.5 Doors and hatch covers needed to ensure watertight integrity of internal openings and which are used during operation of the unit while afloat are to be remotely controlled. Detailed alarm, indication, and control requirements are given in 10.2 for electrically operated watertight doors and hatch covers, and in 10.3 for hydraulically operated watertight doors and hatch covers.

10.1.6 Doors and hatch covers needed to ensure watertight integrity of internal openings which are normally kept closed when the unit is afloat are to be provided with alarm indicators in accordance with 10.4.

10.1.7 Doors and hatch covers needed to ensure watertight and weathertight integrity of external openings are to comply with 10.1.4 and 10.1.5, as appropriate, in accordance with the requirements of Pt 4, Ch 8.

10.1.8 When other types of closing appliances (e.g., on ventilators) are required to be remotely controlled or alarmed in accordance with the requirements of Pt 4, Ch 8, the general requirements of this Section are to be complied with, as applicable.

10.1.9 Bilge level sensors, and water level indication required for column-stabilised units are to be in accordance with 10.5.

10.2 Electrically operated watertight doors and hatches

10.2.1 The requirements for electrically operated watertight doors and hatches are given in Pt 6, Ch 2,18.1 of the Rules for Ships, which are to be complied with where applicable.

10.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with as applicable as in 10.2.3 to 10.2.5.

10.2.3 Where watertight doors and hatch covers are to be operated electrically, the term ‘door’ is to be understood to include hatch covers.

10.2.4 Where the Rules for Ships refer to ‘bulkhead deck’ this should be substituted for ‘final water plane after damage’.

10.2.5 The ‘master mode’ switch is to be Type Approved in accordance with *Test Specification* Number 1 given in LR’s *Type Approval Scheme*.

10.3 Hydraulically operated watertight doors and hatch covers

10.3.1 Where watertight doors and hatch covers are operated hydraulically, the arrangements are to be equivalent to 10.2.1 and 10.2.2 to 10.2.5 for electrically operated doors and hatch covers.

10.3.2 Electrical indication arrangements for hydraulically operated doors and hatch covers are to meet the requirements of 10.2.1 and 10.2.2 to 10.2.5.

10.3.3 Where four or more doors or hatch covers are powered from a single hydraulic power unit, duplicated hydraulic pump units are to be provided.

10.4 Indicators for doors, hatch covers and other closing appliances

10.4.1 Indicators required by 10.1.6 and 10.1.7 on doors, hatch covers and other closing appliances which are intended to ensure the watertight integrity of the unit's structure, are to meet the requirements of 10.4.2 to 10.4.3.

10.4.2 The indicator system is to be designed on the fail-safe principle, such that, in the event of a fault, the system cannot incorrectly indicate that a door, hatch cover, or other closing appliance is fully closed. A green light is to indicate when a door, hatch cover or closing appliance is closed and a red light is to indicate that it is not fully closed or secured.

10.4.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors and hatch covers.

10.5 Bilge level and flood water level alarm and indication

10.5.1 Column-stabilised units are to be provided with arrangements to warn of high bilge level and ingress of water due to flooding in accordance with 10.5.2 to 10.5.4, *see also* Pt 5, Ch 13,8.6.

10.5.2 Bilge high level alarms and water high level alarms are to be provided on a centralised control panel, situated in the ballast control room required by Pt 6, Ch 1,2.8.

10.5.3 Bilge high level or water high level alarm sensors are to be installed in all compartments, which are large enough to affect stability and which are required to remain watertight to comply with the intact and damaged stability criteria. Tanks fitted with remote tank level indicators with displays other than in the ballast control room, are exempt from this requirement. The requirements for chain lockers are to comply with Pt 5, Ch 12,9.2.3.

10.5.4 Pump-rooms, propulsion rooms and machinery spaces category type A in lower hulls and columns are to be provided with two level sensors in each compartment, one for detection of high bilge water level, and a second detector to warn of flooding.

■ *Section 1*
Hazardous areas – General

1.1 Application

1.1.1 Units for oil and gas exploitation, units with production and process plant, drilling plant, and other units where explosive gas-air mixtures are likely to be present are to be classified into 'hazardous areas' and 'non-hazardous areas' in accordance with the requirements of this Chapter, or alternatively, with an acceptable Code or Standard giving equivalent safety.

1.1.2 These requirements do not apply to the release of explosive gas-air mixtures as a consequence of an uncontrolled well blow out or catastrophic failure of pipes or vessels.

1.1.3 For special requirements relating to drilling, workover and wirelining operations, *see* Section 3.

1.1.4 For special requirements relating to units intended for the storage of oil in bulk, *see* Section 9. For special requirements relating to units intended for the storage of liquefied gases in bulk or other hazardous liquids, *see* Sections 10 and 11 and Pt 11, Ch 10.

1.1.5 The hazardous areas applicable to well testing will be specially considered.

1.2 Definitions and categories

1.2.1 A hazardous area is an area on the unit where flammable gas-air mixtures are, or are likely to be, present in sufficient quantities and for sufficient periods of time such as to require special precautions to be taken in the selection, installation and use of machinery and electrical equipment.

1.2.2 Hazardous areas may be divided into Zones 0, 1 and 2, defined as follows:

Zone 0: An area in which an explosive gas-air mixture is continuously present or present for long periods.

Zone 1: An area in which an explosive gas-air mixture is likely to occur under normal operating conditions.

Zone 2: An area in which an explosive gas-air mixture is unlikely to occur, and if it occurs, it will only persist for a short period.

Non-hazardous areas are those which are not classified as hazardous according to the above definitions.

1.2.3 An enclosed space is considered to be any building, room or enclosure, e.g., cabinet, within which, in the absence of artificial ventilation, the air movement will be limited and any flammable atmosphere will not be dispersed naturally.

1.2.4 A semi-enclosed space is considered to be a space which is adjoining an open area where the natural ventilation conditions within the space are restricted by structures such as decks, bulkheads or windbreaks in such a manner that they are significantly different from those appertaining to the open deck, and where dispersion of gas may be impeded.

1.2.5 When an enclosed or semi-enclosed space is provided with a mechanical ventilation system which ensures at least 12 air changes/hour and no pockets of stagnant air within the space, such a space may be regarded as an open space.

1.2.6 An open space is an area that is open-air without stagnant regions where vapours are rapidly dispersed by wind and natural convection. Typically, air velocities will rarely be less than 0,5 metres per second and will frequently be above 2 metres per second.

1.2.7 Under normal operating conditions, a hazardous zone or space may arise from the presence of any of the following:

(a) Spaces or tanks containing any of the following:
   (i) Flammable liquid having a flash point not exceeding 60°C closed-cup test;

(ii) Flammable liquid having a flash point above 60°C closed-cup test, heated or raised by ambient conditions to a temperature within 15°C of its flash point;
(iii) Flammable gas.

(b) Piping systems or equipment containing fluid defined by (a) and having flanged joints, glands or other fittings through which leakage of fluid may occur.

(c) Piping systems or equipment containing flammable liquid not defined by (a), and having flanged joints, glands or other fittings through which leakage of fluid in the form of a fine spray or mist could occur.

(d) Equipment associated with processes such as battery charging or electrochlorination which generate flammable gas as a by-product, and having vents or other openings from which gas may be released.

1.2.8 Release of explosive gas-air mixtures may be categorised into continuous, primary and secondary grades:

(a) Continuous grades of release include the following:
(i) The surface of a flammable liquid in a closed tank or pipe.
(ii) A vent or other opening which releases flammable gases or vapours frequently, continuously or for long periods.

(b) Primary grades of release include the following:
(i) Pumps and compressors with standard seals, and valves, flanges and fittings containing flammable fluids if release of fluid to atmosphere during normal operation may be expected.
(ii) Sample points and process equipment drains, which may release flammable fluid to atmosphere during normal operation.
(iii) Pig launcher and receiver doors, which are opened frequently.
(iv) Vents which frequently release small quantities, or occasionally release larger quantities, of flammable gases to atmosphere.
(v) Tanks or openings of the active mud circulating system between the well and the final degasser discharge, which may release gas during normal operation.
(vi) Drilling operations in enclosed or semi-enclosed spaces, *see* Section 3.

(c) Secondary grades of release, include the following:
(i) Pumps and compressors, and valves, flanges and fittings containing flammable fluids.
(ii) Vents which release flammable gases intermittently to atmosphere.
(iii) Tanks or openings of the mud circulating system from the final degasser discharge to the mud pump connection at the mud pit.
(iv) Drilling, workover and wirelining operations in open spaces, *see* Section 3.

1.3 Documentation

1.3.1 Single copies, unless otherwise stated, of the following documentation on 'hazardous areas' are to be submitted for consideration:

- Hazardous area classification philosophy.
- Hazardous area classification design specifications.
- Facility layout plans (plot plans).
- Hazardous area classification schedule (data sheets), *see also* 1.3.2.
- Hazardous area classification plans.

1.3.2 It is expected that the data sheets, referred to in 1.3.1, include, but are not limited to, the following information:

- Equipment identification.
- Operating conditions.
- Media and media properties.
- Fluid category.
- Sources of potential release.
- Grades of release.
- Venting rates.
- Hazardous zones determined.
- Dimension of each hazardous zone.
- Code or Standard used for reference.

1.3.3 Single copies, unless otherwise stated, of the following plans and particulars on 'ventilation' are to be submitted for consideration:

- Ventilation design philosophy.
- Ventilation design specifications.
- Ventilation layout plans.
- Ducting and instrumentation plans (D & IDs).

■ *Section 2* Classification of hazardous areas

2.1 General

2.1.1 The hazardous areas as specified may be extended or restricted depending on conditions such as fluid system pressure and composition, or by the use of structural arrangements such as fire walls, windshields, special ventilation arrangements, etc. For special requirements relating to units intended for the storage of oil in bulk, *see* Section 9. For special requirements relating to units intended for the storage of liquefied gases in bulk or other hazardous liquids, *see* Sections 10 and 11 and Pt 11, Ch 10.

2.1.2 Relatively small non-hazardous areas surrounded by or confined by hazardous areas, or Zone 2 areas within Zone 1 areas, are to be classified as the adjacent surrounding hazardous area.

2.1.3 For gas disposal systems, other than permanently ignited flares, and for vents for large quantities of hydrocarbon gas from production facilities, the classification and extent of the surrounding hazardous areas should be based on dispersion calculations.

2.1.4 For permanently ignited flares, consideration is to be given to possible 'flame out' conditions or intentional periods of cold venting and the hazardous areas created by such are to be determined.

2.1.5 Within these Rules, all reference to the extent of the hazardous zones given as a radius, refers to the horizontal extent of the zone, except where specifically stated as being a spherical zone; for vertical extent of zones, *see* 2.5.

2.2 Zone 0

2.2.1 Areas to be classified as Zone 0 include:

(a) The internal space of a closed tank or pipe containing a flammable liquid or gas, crude oil or active mud, or a space where an oil-gas-air mixture is continuously present, or present for long periods;

(b) Unventilated spaces containing a source of release (i.e., flange, valve, etc.) separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas; and

(c) A region around the outlet from non-pressurised tank vents or other sources, or from cold vents where discharge, which releases flammable gases or vapours frequently, continuously or for long periods. The size of this hazardous region should be based on guidance from a recognised Standard (i.e., EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling.

2.3 Zone 1

2.3.1 Areas to be classified as Zone 1 include:

(a) Adequately ventilated closed or semi-enclosed spaces containing primary grades of release, *see* 1.2.8(b);

(b) Mechanically ventilated closed spaces containing a source of release (i.e., flange, valve, etc.) separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas. Or an unventilated closed space not containing any sources of release separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas;

(c) In open spaces, the area surrounding a primary grade of release. The extent of the Zone 1 hazardous area will be based upon the primary grade source of release. The size of this hazardous region should be based on guidance from a recognised Standard (i.e., EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling.

(d) In open spaces, the area within 3 m from pig launcher and receiver doors. This may be reduced to 1,5 m if the equipment is washed through with nitrogen or water washed before opening;

(e) In open spaces, the area local to any opening associated with an enclosed Zone 1 area, any ventilation outlet from a Zone 1 space, or any access, such as a doorway or non-bolted hatch to an enclosed Zone 1 hazardous area, is to be classified as a Zone 1 space. The extent of the external Zone 1 hazardous area will be based upon the largest source of release with the enclosed Zone 1 area based on guidance from a recognised Standard (i.e., EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling;

(f) Semi-enclosed spaces, such as inadequately ventilated pits, ducts or similar structures situated in locations which would otherwise be a Zone 2, but where their arrangement is such that gas dispersion cannot easily occur.

(g) For units containing drilling facilities, specific reference is to be made to the requirements given in the 2009 MODU Code Chapter 6 regarding the extent of Zone 1 hazardous areas on MODUs as well as the following Section 3 and the guidance given in EI (formerly IP) Part 15 for drilling facilities.

(h) For tanker storage facilities containing flammable liquids or flammable liquefied gases, reference is to be made to requirements given in IEC 60092-502 regarding the extent of Zone 1 hazardous areas. Additionally, for tanker storage facilities containing flammable liquefied gases specific reference is to be made to Pt 11, Ch 10 regarding the extent of the Zone 1 hazardous area.

2.4 Zone 2

2.4.1 Areas to be classified as Zone 2 include:

(a) Adequately ventilated closed or semi-enclosed spaces containing secondary grades of release, *see* 1.2.8(c);

(b) In open spaces, the area beyond the Zone 1 specified in 2.3.1(c) and (d), and beyond the semi-enclosed space specified in 2.3.1(f). The extent of the Zone 2 hazardous area will be based upon the primary grade source of release. The extent of the external Zone 2 hazardous area will be based upon the largest source of release with the enclosed Zone 1 area based on guidance from a recognised Standard (i.e., EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling;

(c) In open spaces, the area surrounding a secondary grade of release, any ventilation outlet from a Zone 2 space or any access to a Zone 2 space. The extent of the Zone 2 hazardous area will be based upon the source of release based on guidance from a recognised Standard (i.e., EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling;

(d) Mechanically ventilated closed spaces not containing a source of release separated by a single gastight bulkhead or deck from a tank containing flammable liquid or gas;

(e) For units containing drilling facilities, specific reference is to be made to the requirements given in the 2009 MODU Code Chapter 6 regarding the extent of Zone 2 hazardous areas on MODUs as well as the following Section 3 and the guidance given in EI (formerly IP) Part 15 for drilling facilities;

(f) For tanker storage facilities containing flammable liquids or flammable liquefied gases, reference is to be made to requirements given in IEC 60092-502 regarding the extent of Zone 2 hazardous areas. Additionally, for tanker storage facilities containing flammable liquefied gases specific reference is to be made to Pt 11, Ch 10 regarding the extent of the Zone 2 hazardous area and;

(g) Air locks between a Zone 1 and a non-hazardous area, *see* 4.1.3 (c); and

(h) For drilling units, specific reference is to be made to the requirements given in the 2009 MODU Code Chapter 6 regarding the extent of Zone 2 hazardous areas on MODUs, as well as the following Section 3.

2.5 Vertical extent of hazardous zones

2.5.1 The relationship between the hazard radius and the full 3-dimensional envelope of the hazardous area is dependent upon the height and orientation of the release and the hazard radius. If the release height and the generated hazardous radius zone are greater than 1 m above the deck, then the developed hazardous area is independent of potential hazardous accumulations of flammable releases at deck level. If the release height and the generated hazard radius are less than 1 m above the deck, then the developed hazardous area is dependent on potential hazardous accumulations of flammable releases at deck level and the subsequent hazardous area needs to take into account the generated hazardous area at deck level. The vertical extent of a hazardous area should be based on guidance from a recognised Standard (i.e., EI (formerly IP) Part 15, API RP 505, IEC 60092-502, IEC 61892-7, EN60079-10-1, 2009 MODU Code) or established through distribution modelling.

2.5.2 For tanker storage facilities containing flammable liquids or flammable liquefied gases, reference is to be made to requirements given in IEC 60092-502 regarding the vertical extent of a hazardous area. Additionally, for tanker storage facilities containing flammable liquefied gases specific reference is to be made to Pt 11, Ch 10 regarding the vertical extent of a hazardous area.

■ *Section 3*
Hazardous areas – Drilling, workover and wirelining operations

3.1 General

3.1.1 This hazardous area classification applies to any part of the drilling derrick or equipment which could potentially release oil or gas from the well, including equipment that is required to operate under controlled emergency conditions, such as during a blow out.

3.1.2 The requirements of Section 2 are also to be complied with, where applicable.

3.2 Classification

3.2.1 For units containing drilling facilities, specific reference is to be made to the requirements given in the 2009 IMO MODU Code Resolution A.1023(26) Ch 6 regarding the extent of hazardous areas on MODUs. However, it must be recognised that other recognised Standards (i.e., EI (formerly IP) Part 15) give additional and potentially different hazardous area guidance associated with drill rigs and facilities. As such, the guidance given in these alternative Standards may be more applicable to the drilling facilities associated with the installation to be classified.

■ *Section 4*
Enclosed and semi-enclosed spaces with access to a hazardous area

4.1 General

4.1.1 As far as practicable, access doors or other openings should not be provided between a non-hazardous space and a hazardous area or space, or between a Zone 2 space and a Zone 1 space.

4.1.2 Where such openings are necessary, an enclosed or semi-enclosed space with a direct access door or opening leading to an area or space which is of a greater hazard classification is to be regarded as the same hazard classification as the area or space into which this door or opening leads, except where suitable arrangements as permitted by 4.1.3 are provided.

4.1.3 An enclosed space with direct access to a:

(a) Zone 1 hazardous area may be classified as Zone 2 provided that:
   - (i) The access is fitted with a self-closing, gastight door that opens into the Zone 2 space;
   - (ii) Ventilation is such that the air flow with the door open is from the enclosed space to the Zone 1 hazardous area; and
   - (iii) Loss of ventilation is alarmed at a manned control station.

(b) Zone 2 hazardous area may be classified as non-hazardous provided that:
   - (i) The access is fitted with a self-closing, gastight door that opens into the non-hazardous space;
   - (ii) Ventilation is such that the air flow with the door open is from the non-hazardous space to the Zone 2 hazardous area; and
   - (iii) Loss of ventilation is alarmed at a manned control station.
   - (iv) The enclosed space is maintained at an over-pressure of at least 50 Pa relative to the external hazardous area.

(c) Zone 1 hazardous area may be classified as non-hazardous provided that:
   - (i) The access is via a mechanically ventilated airlock consisting of two self-closing, gastight doors without any hold-back arrangement, and spaced at least 1,5 m but not more than 2,5 m apart;
   - (ii) The enclosed space is maintained at an overpressure of at least 50 Pa relative to the external hazardous area; and
   - (iii) The relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given at a manned control station.

4.1.4 Where one of the doors specified in 4.1.3(c)(i) is required to be weathertight or watertight and the provision of a self-closing mechanism would be impracticable, consideration will be given to waiving the requirement for this door to be self-closing, provided the door is normally kept closed and is provided with a notice to this effect.

Section 5
Machinery in hazardous areas

5.1 General

5.1.1 Installation of mechanical equipment within hazardous areas should be limited to that considered to be necessary for operational purposes within that area. Wherever possible, the installation of fired equipment or internal combustion machinery in hazardous areas should be avoided.

5.1.2 Where it is considered necessary for mechanical equipment or machinery to be installed in a hazardous area, it is to be constructed and installed so as to reduce the risk of sparking due to friction between moving parts or the formation of static electricity, or to ignition due to exposed high-temperature exhausts, etc., *see also* Pt 5, Ch 14,3.13.

5.1.3 Air compressors are not, in general, to be installed in hazardous areas. However, where this is not practicable, such installation may be accepted provided that the air inlet is from a non-hazardous area in accordance with 6.4, and that the inlet ducting is fitted with suitable gas detectors arranged to give an audible and visual alarm and to shut down the compressor in the event of flammable and/or toxic gases entering the air inlet.

5.1.4 Fans located in hazardous areas are to be of the non-sparking type.

5.1.5 For the requirements appertaining to the installation of suitably protected oil engines in a Zone 2 hazardous area, *see* Section 7.

5.1.6 Wherever possible, piping system arrangements are to preclude direct communication between hazardous and non-hazardous areas, and between hazardous areas of different classifications. Where pipes, ducts or cables pass through decks or bulkheads, the penetration is to be designed to prevent the passage of hazardous gases.

5.1.7 Maintenance hatches and removable panels are to be provided with suitable seals to prevent the passage of hazardous gases when closed.

5.1.8 When oil storage pumps and ballast pumps in dangerous or hazardous spaces are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by Table 2.5.1, as appropriate. Alternative arrangements which provide equivalent safeguards will be considered. The design of the alarm, control and safety systems is to comply with the requirements of Pt 6, Ch 1,2. Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could cause hazard.

Table 2.5.1 Alarm and safety arrangements

Item	Alarm	Note
Bulkhead gland temperature	High	Any machinery item
Bearing temperature	High	Any machinery item
Pump casing temperature	High	‘Oil storage’ pumps only
Bilge level	High	
Hydrocarbon concentration	High	>20% LEL

Section 6
Ventilation

6.1 General requirements

6.1.1 Mechanical ventilation systems are to be capable of continuous operation by the provision of adequate standby/redundancy capable of maintaining the required flow rates and pressure differentials. Machinery spaces are, where practicable, to be served by redundant air intake ducts.

6.1.2 Open or semi-enclosed spaces which are designed to be ventilated by natural means are to achieve a minimum of 12 air changes per hour for 95 per cent of the time. This natural ventilation may be augmented by mechanical means.

6.1.3 Non-hazardous enclosed spaces are to be maintained with an overpressure of at least 50 Pa in relation to any adjacent more hazardous areas or spaces. The non-hazardous area ventilation with positive pressurisation is to be designed to help mitigate against potential gas ingress to the non hazardous area so that where there is any doorway, hatch or other opening in the contiguous boundary, the ventilation helps to prevent the transmission of fluids from the more hazardous area or space to the less hazardous space.

6.1.4 Accommodation spaces are to be maintained at a positive pressure in relation to the outside atmosphere.

6.1.5 Ventilation services to drilling utilities areas and to wellhead areas should, where practicable, be separate from services to other hazardous areas.

6.1.6 Air supplied for combustion and/or cooling of engines or other fuel-burning equipment is to be supplied separately from general ventilation services. The ventilation system for engine or boiler rooms is to be independent of all other ventilation systems. Induced draught fans, or a closed system of forced draught may be employed for fired equipment, or the fired equipment may be enclosed in a pressurised air casing.

6.1.7 System design is to be arranged for individual isolation to enable continuity of operation and purging of spaces following contamination.

6.1.8 The system design is to take due regard to the possible weathervaning of the unit and periods when the current is the prevailing factor, such that the air intake, at low wind speeds, may be partially starved of air.

6.1.9 Ducting materials, including associated fittings, are to be of a non-combustible material, to be of all welded construction adequate to withstand likely damage and corrosion and to be suitable for a marine saline atmosphere. Ventilation fans are to have non-overloading, non-stall characteristics and are to be fitted with anti-sparking tracks.

6.1.10 For aspects of ventilation systems relating to fire integrity, *see* Chapter 3, and for gas detection requirements, *see* Ch 1,5.

6.2 Ventilation of hazardous spaces

6.2.1 Ventilation systems and ducting for spaces designated as hazardous areas are to be entirely separate from ventilation systems and ducting for spaces designated as non-hazardous areas.

6.2.2 All enclosed hazardous spaces are to be adequately ventilated by a mechanical ventilation system providing at least 12 air changes per hour. Air change calculations are to be based upon empty volume of space. The mechanical ventilation is to be such that hazardous enclosed spaces are maintained with an underpressure of at least 50 Pa in relation to any adjacent less hazardous areas or spaces.

6.2.3 To ensure that the required relative underpressure is maintained in any hazardous enclosed space, the supply and exhaust fans are to be interlocked so that the supply fan cannot be run unless the exhaust fan is running.

6.2.4 Ventilation arrangements should ensure that the entire space is adequately ventilated, giving an even air distribution, with special consideration to locations where there is equipment which may release gas, and to locations within the space where stagnant pockets of gas could accumulate.

6.2.5 Electric heating elements are to be fitted with automatic temperature control, a high temperature alarm and an independent sensor and cut-out with manual reset. The surface temperature is to be restricted to a maximum of 200°C, or below the ignition temperature of any flammable gas likely to be present in the area.

6.2.6 The presence of gas within the enclosed hazardous area and/or the ventilation system air extracts from this area is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area. In these circumstances all ventilation equipment must be rated to operate in a Zone 1 hazardous area.

6.3 Ventilation of other spaces containing sources of hazard

6.3.1 Ventilation systems and ducting for any space containing a source of release of a flammable substance, but not designated as a hazardous space in its entirety (e.g., by virtue of compliance with 1.2.5), are to be entirely segregated from ventilation systems and ducting for other non-hazardous areas or spaces.

6.3.2 The mechanical ventilation is to be such that the space and ducting serving it is maintained at an underpressure of at least 50 Pa in relation to adjacent non-hazardous areas or spaces.

6.3.3 Where the ventilation air flow rate within the space in relation to the maximum release rate of flammable substances reasonably to be expected under normal operating conditions is sufficient to prevent any concentration of flammable substances approaching their lower explosive limit, consideration will be given to regarding the entire space, including the zone around equipment contained within it, its ventilation systems and other openings into it, as non-hazardous. Ventilation airflow is to be monitored and appropriate measures taken in the event of failure. For requirements particular to gas turbine rooms and hoods, *see* 6.5.

6.3.4 The presence of gas within the enclosed hazardous area and/or the ventilation system air extracts from this area is not to initiate the shut-down of the area's ventilation system as this will result in the build-up of hazardous gas in this area. In these circumstances all ventilation equipment must be rated to operate in a Zone 1 hazardous area.

6.4 Location of air intakes and exhausts

6.4.1 Supply air intakes are to be located in external non-hazardous areas, at least 3 m from the boundary of any hazardous area.

6.4.2 The siting of supply air intakes should be such as to avoid the possibility of drawing in combustion products from equipment exhausts or hazardous/toxic gases from process equipment.

6.4.3 Ventilation intake and outlet ducts should not pass through spaces of different classification. Where this is unavoidable, ducts may pass through a more hazardous space than the ventilated space provided; such ducts have an overpressure in relation to the space through which they pass. Where necessary, ducts should be of welded, gastight construction. The internal space of such ducts is to have the same zone classification as the ventilated space.

6.4.4 Ventilation outlets are, as far as is practicable, to be located in external areas of the same or lesser zone classification as the ventilated space. Where this is not practicable, appropriate measures are to be taken to prevent backflow into the ventilated space, in the event of ventilation failure.

6.4.5 The separation between air intakes and outlets should be at least 4,5 m. The siting of inlets and outlets should be such as to avoid the possibility of cross-contamination.

6.4.6 Ventilation intakes and outlets are to be located and arranged to avoid ingress of rain, snow and sea-water, even under predicted worst storm conditions.

6.4.7 Gas turbine intakes and exhausts are to be positioned well clear of the unit's structure. Turbine exhausts are to be safely located, so as not to endanger personnel or interfere with helicopter operations.

6.4.8 Where practicable, ventilation outlets from non-hazardous areas should not discharge into a hazardous area.

6.4.9 Air intakes for internal combustion engines (unless certified for use in a Zone 2 hazardous area), fired boilers and other fired units are to be located at least 3 m from hazardous areas.

6.5 Gas turbine ventilation

6.5.1 The turbine room is to be designed as a non-hazardous space, mechanically ventilated with at least 12 air changes per hour and arranged so that an overpressure of at least 50 Pa is maintained in relation to the turbine hood.

6.5.2 The turbine hood is to be mechanically ventilated by means of one duty and one 100 per cent stand-by extraction fan with a ventilation rate to remove adequately heat from the turbine and equipment, and to dilute any flammable gas. Potential leakage from under the turbine hood is to be considered. The ventilation rate is to be at least 12 air changes per hour and arranged so that an underpressure of at least 50 Pa is maintained in relation to the turbine room. On failure of the duty fan, an alarm is to be given in the control room and the stand-by fan automatically activated.

6.5.3 Provided it can be shown that no exposed surface of the turbine or equipment inside the hood will have a surface temperature exceeding 200°C, or that the surface temperature will not exceed 80 per cent of the auto-ignition temperature of any flammable gas which may be present, the ventilation rate may be as per 6.5.2 where the turbine is in operation. Under these conditions, the space inside the hood will be classified as a Zone 2 hazardous area.

6.5.4 Where the surface temperature of the turbine or equipment inside the hood could exceed 80 per cent of the auto-ignition temperature of any flammable gas which may be present, the space inside the hood is to be ventilated with at least 90 air changes per hour. Under these conditions, the turbine hood need not be classified as a hazardous area when the turbine is in operation.

6.5.5 The turbine hood ventilation fans referred to in 6.5.2 are to be interlocked with the turbine starting sequence, to provide at least five air changes in the turbine hood before start up of the turbine or the energising of any associated electrical equipment, other than that suitable for installation in a Zone 1 location. On shut-down, the duty fan is to purge the turbine hood until the turbine has stopped. At least one of the fans is to be supplied from an emergency power source. *See also* Pt 6, Ch 2,3.7.9.

6.5.6 Equipment which is required to remain activated after shut-down or hood ventilation failure, is to be certified for use in a Zone 1 hazardous area.

6.5.7 Gas detectors are to be installed inside the turbine hood to shut down the turbine on detection of gas.

6.5.8 For gas turbines utilising gas fuel from the production and process facility, the arrangement and capacities of the ventilation system and fuel gas piping are to comply, where applicable, with the requirements of Pt 5, Ch 16, taking into account any additional requirements which may be necessary during start-up or shut-down of the plant.

■ *Section 7*
Oil engines in hazardous areas

7.1 Application

7.1.1 Oil engines are not permitted in Zone 0 and Zone 1 hazardous areas on offshore installations. Oil engines which are required to operate in Zone 2 hazardous areas are to comply with the requirements of 7.1.2 to 7.1.23. National Standards and Government Regulations or Codes of Practice which differ from these requirements may also be accepted, provided an equivalent standard of protection is achieved.

7.1.2 The air induction system is to be provided with a shut-off valve located between the engine air inlet filter and the flame arrester. The valve is to be capable of being closed manually. The valve is also to be capable of being automatically closed by the engine overspeed device and consideration should be given to provision being made so that the induction air valve and engine fuel supply should automatically close by a signal from a local gas sensor.

7.1.3 An approved corrosion resistant flame arrester, constructed and tested to a recognised Standard, is to be provided in the induction system. The flame arrester is to be as close to the engine as possible with good access for inspection and overhaul.

7.1.4 Joints used in the induction and exhaust systems are to be designated either as 'open joints' or 'closed joints'.

7.1.5 An open joint will allow the free passage of gas but will not allow the passage of flame. The dimensions of such a joint are to be determined in accordance with Fig. 2.7.1. A flame arrester is a particular type of open joint considered separately by testing.

7.1.6 A closed joint will not allow the passage of either gas or flame under normal or test conditions.

7.1.7 An approved corrosion resistant flame arrester is to be provided in the exhaust system. The flame arrester is to be constructed and tested to a recognised Standard. The flame arrester is to be fitted as close to the engine as possible, with good access for inspection and replacement. The flame arrester can be omitted if the exhaust terminates in a non-hazardous area.

7.1.8 A spark arrester is to be fitted in the exhaust system downstream of the flame arrester. The spark arrester is to be constructed and tested to a recognised Standard.

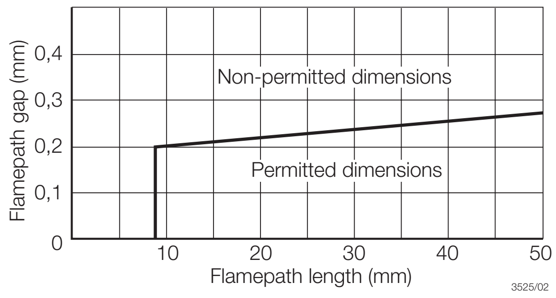

Fig. 2.7.1
Relationship between length and gap for flamepaths

7.1.9 Consideration should be given to a back pressure indicator being fitted to the exhaust manifold to provide prior warning of exhaust flame arrester fouling.

7.1.10 The engine crankcase breather pipe is to be fitted with a flame arrester. For engines in enclosed Zone 2 areas, the breather pipe is to be led to the open atmosphere. The breather pipe is not to be led to the engine induction system.

7.1.11 The engine crankcase is to operate at a small positive pressure.

7.1.12 With the engine at maximum continuous rating and temperatures stabilised, no surface temperature on the engine or exhaust system is to exceed 200°C.

7.1.13 Ventilation fan blades and belts are to be of the anti-static type. The combination of materials for fan impellers and the housing are to be non-sparking under both normal and fault conditions.

7.1.14 Engine starting systems are not to introduce a source of ignition external to the engine. The system is to have appropriate safe-type certification, or to be capable of being demonstrated as being of a safe-type by appropriate testing.

7.1.15 The engine is not to be capable of running in reverse.

7.1.16 Fuel supply is to be capable of being shut off manually and automatically in the event of:

- Overspeeding;
- High exhaust temperature, *see* 7.1.17;
- High cooling water temperature; or
- Low lubricating oil pressure.

7.1.17 The high exhaust temperature sensor is to be located upstream of the exhaust flame arrester. The high exhaust temperature sensor and engine shut-down on high exhaust temperature can be omitted if the exhaust pipe terminates in a safe area.

7.1.18 Basic operating instructions should be permanently attached to the unit giving details of stop, start and emergency procedures.

7.1.19 Where an engine is fitted inside any enclosure, the following requirements are to be complied with, as applicable:

(a) Where an engine is located inside an enclosed Zone 2 hazardous area, the space is to be independently ventilated at a recommended minimum rate of 20 air changes per hour whilst the engine is running and 12 air changes per hour when stopped.

(b) For engines placed inside enclosures of any type, it is recommended that fire and gas sensors be provided inside the enclosure are suitably alarmed to a continuously manned control room.

7.1.20 A hydraulic proof test at a gauge pressure of 5 bar or 1,5 times the maximum pressure obtained in explosion tests in accordance with 7.1.21 is to be witnessed on the induction and exhaust system components without showing signs of leakage.

7.1.21 For engines of 370 kW (500 shp) and above, the induction and exhaust systems are to be explosion tested to a recognised Standard without showing signs of damage or flame transmission to the atmosphere. The maximum explosion pressure is to be recorded and used in the hydraulic proof test in 7.1.20.

7.1.22 Complete engine units and driven components are to be examined and tested at the manufacturer's works or other suitable works before being put into service. Thereafter, the complete unit is to be examined annually and the original certificate endorsed or as otherwise agreed to ensure a permanent written record of survey. It is recommended that time clocks of the non-resetting type be fitted to the engine.

7.1.23 Where an engine manufacturer carries out satisfactory type tests on an engine or series of engines and subsequently provides conversion kits for similar engines, proof tests can be waived. However, each converted engine is to be shop tested in accordance with 7.1.22.

■ *Section 8*
Electrical equipment for use in explosive gas atmospheres

8.1 General

8.1.1 The requirements for electrical equipment for use in explosive gas atmospheres are given in Pt 6, Ch 2,14.1, 14.2 and 14.9 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), which are to be complied with where applicable.

8.1.2 Additional or amended requirements are given in 8.1.3 to 8.1.14.

8.1.3 In locations classified as Zone 0, and in various enclosed spaces identified in Section 9, only intrinsically safe equipment of category 'ia', or simple apparatus as defined in Pt 6, Ch 2,14.2.4(b) of the Rules for Ships and complying in full with the relevant requirements of IEC 60079 for intrinsic safety, category 'ia', is permitted.

8.1.4 In locations classified as Zone 1 and in spaces and locations identified in Section 9 as permitting the installation of safe type equipment, other than locations described in 8.1.5, only the following equipment may be installed:

- Equipment having a type of protection listed under Pt 6, Ch 2,14.2.5 of the Rules for Ships.
- Equipment as described under Pt 6, Ch 2,14.2.6(c) of the Rules for Ships, arranged to be de-energised automatically on loss of pressurisation.

8.1.5 In locations classified as Zone 2, and on open deck in well ventilated positions not within 3 m of any flammable gas or vapour outlet, equipment having the types of protection listed under Pt 6, Ch 2,14.2.5 of the Rules for Ships, or as described under Pt 6, Ch 2,14.2.6(a) to (d) of the Rules for Ships may be installed.

8.1.6 Any electrical equipment which has to remain operational during a Major Accident Event (e.g., rupture of a process vessel or pipe), whether or not installed in a hazardous zone or location, is to be suitable for use in an explosive gas atmosphere. Such equipment is to be of a type permitted within Zone 1 locations, unless it is demonstrated that the equipment is appropriately protected against potentially coming into contact with a flammable atmosphere by being located in an enclosed safe area with appropriate mitigating measures (i.e., enclosed safe area is equipped with gastight barriers, gastight doors, rated gas dampers, suitable gas detection within the enclosure and its ventilation air intakes, etc.).

8.1.7 Flame-proof enclosures and intrinsically safe electrical apparatus, and apparatus incorporating flame-proof or intrinsically safe components or otherwise tested or certified for particular groups, with reference to the group(s) of gas(es) that may be present, is to be selected with reference to IEC/TR 60079-20: *Electrical apparatus for explosive gas atmospheres – Part 20: Data for flammable gases and vapours*, relating to the use of electrical apparatus.

8.1.8 The electrical apparatus shall be so selected that its maximum surface temperature as indicated by its temperature class, or otherwise documented, will not reach the auto-ignition temperature of any gas or vapour, or mixture of gases or vapour, which can be present. The ambient temperature range for which the apparatus is certified is to be taken to be minus 20°C to 40°C, unless otherwise stated, and account is to be taken of this when assessing the suitability of the equipment for the auto-ignition temperature of the gases encountered.

8.1.9 Cables are not permitted to pass through locations classified as Zone 0, and are permitted to enter such locations only where required for the operation of any electrical equipment located therein.

8.1.10 Cables are to be either:

(a) Mineral insulated with copper sheath; or
(b) Armoured or braided, except where:
 (i) The cable is associated with an intrinsically safe circuit; or
 (ii) The cable does not pass into or through any location classified as Zone 1, and is routed or protected so as to present only a low risk of mechanical damage; or
 (iii) A cable of flexible construction is demanded by operational requirements, and its construction, routing and means of support are such as to present only a low risk of mechanical damage; or
 (iv) The cable is installed within a conduit system meeting the relevant requirements of IEC60079-14.

8.1.11 Metal coverings of cables installed in hazardous zones or spaces are to be effectively earthed at both ends, at least, except where otherwise permitted by IEC 60079-14.

8.1.12 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g., neither installed in the same protective casing nor secured by the same fixing clip, except where alternative arrangements are permitted by IEC 60079-14.

8.1.13 No more than one intrinsically safe circuit should be run in any multicore cable unless:

(a) No circuit is required to be of category ‘ia’, and either:
 (i) The cable is run or protected so as to present little risk of its suffering mechanical damage; or
 (ii) Each intrinsically safe circuit is contained within an earthed metallic screen; or
(b) It can be shown that no combination of faults between the intrinsically safe circuits within the cable can lead to an unsafe condition.

8.1.14 Cabling, wiring, and connections within enclosures containing more than one intrinsically safe circuit, or containing both intrinsically safe and other circuits, are to be arranged in accordance with the relevant requirements of IEC60079-11 and IEC60079-14 so as to minimise the risk of inadvertent interconnections between different circuits.

■ *Section 9*
Additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test)

9.1 General

9.1.1 The additional requirements for electrical equipment on oil storage units for the storage of oil in bulk having a flash point not exceeding 60°C (closed-cup test) are given in this Section.

9.1.2 Spaces or locations associated with or close to the arrangements for oil storage, loading and discharging are to be classified into hazardous zones, and electrical equipment is to be selected and installed, in accordance with IEC 60092-502: *Electrical Installations in Ships – Tankers – Special Features*.

9.1.3 Alternatively, classification of these spaces or locations may be carried out by application of the methods given in IEC Publication 60079-10-1 or EI (formerly IP) Part 15, taking into account the probable frequency, duration and rates of leakages of flammable material from all sources (including structural defects) and the degree and availability of ventilation at the location. The selection and installation of electrical equipment is to meet the requirements of Section 8 for the relevant zone.

9.1.4 In addition to the requirements of Section 8, cables, other than those of intrinsically safe circuits, in hazardous zones or spaces, or which may be exposed to stored oil, oil vapour or gas, are to be either:
(a) mineral insulated with copper sheath; or
(b) armoured or braided (for mechanical protection and earth detection) with non-metallic impervious sheath.

9.1.5 Where electrical equipment is not suitable for a hazardous area into which the space has an opening, the electrical supply to the equipment is to be disconnected, provided shutting down the equipment will not introduce a hazard. In this case, an alarm may be given, in lieu of shut-down, upon loss of overpressure or ventilation, and a means of disconnection of the electrical equipment, capable of being controlled from a manned station, provided in conjunction with an agreed operational procedure. Where the means of disconnection (whether controlled automatically or manually) is located within the space, it is to be equipment of a type suitable for use in a Zone 1 location.

9.1.6 Within any space classified as safe by virtue of pressurisation, any electrical equipment required to operate upon loss of overpressure and lighting fittings and equipment within the air-lock is to be of a type suitable for a Zone 1 location. Means are to be provided to prevent electrical equipment, other than that suitable for a Zone 1 location, being energised until the atmosphere within the space is made safe, by air renewal of at least 10 times the internal volume of the space.

■ *Section 10* Additional requirements for electrical equipment on units for the storage of liquefied gases in bulk

10.1 General

10.1.1 *See* Pt 11, Ch 10.

■ *Section 11* Additional requirements for electrical equipment on units intended for the storage in bulk of other flammable liquid cargoes

11.1 General

11.1.1 *See* Chapter 10 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquid Chemicals in Bulk.*

■ *Section 12* Requirements for units with space for storing paint

12.1 General

12.1.1 The In order to eliminate potential sources of ignition in paint stores, electrical equipment is to be selected as follows:
(a) electrical equipment fitted within the space and within the exhaust ventilation trunking for the space is to be of a type acceptable for zone 1;
(b) electrical equipment situated within 1m of inlet and exhaust ventilation openings or within 3m of exhaust mechanical ventilation outlets is to be of a type acceptable for zone 2, or is to have an enclosure of ingress protection rating of at least IP55, *see* IEC 60529, Classification of Degrees of Protection Provided by Enclosures. *See* Pt 6, Ch 2,1.11.1 for degrees of protection required for equipment on open deck.

12.1.2 A space having access to a paint store may be regarded as non-hazardous if fulfilling all the following conditions:
(a) access is by means of a self-closing gastight steel door without any hold-back arrangement;
(b) the paint store is ventilated from a non-hazardous area;
(c) warning notices are fitted adjacent to the paint store entrance warning of flammable liquids contained in paint store.

NOTE
A watertight door may be considered as being gastight.

12.1.3 The relevant group and temperature class for electrical equipment in hazardous zones are, respectively, IIB and T3.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements for fire and gas detection systems and other safety systems are to be in accordance with Chapter 1. The requirements for hazardous areas and ventilation are to comply with Chapter 2.

1.1.2 Compliance with the requirements for fire safety of the National Administrations in the area where the unit is located and/or the country in which the unit is registered, is to be demonstrated by the issue of appropriate certification in accordance with Pt 1, Ch 2,1.

1.1.3 In addition to the requirements of 1.1.1 and 1.1.2, units with production and process plant are to comply with the additional requirements given in Section 3.

1.1.4 Units with crude oil storage tanks are, in general, to comply with the relevant requirements for tankers detailed in SOLAS Ch II-2 and IMO *International Code for Fire Safety Systems (FSS)* (hereinafter referred to as FSS Code). Where this is not practicable owing to the general construction of the unit, special consideration will be given to other arrangements which provide equivalent protection, *see also* Pt 3, Ch 3,1.4.

1.1.5 The definitions given in Section 2 are, in general, in accordance with the IMO *Code for the Construction and Equipment of Mobile Drilling Units, 2009* (hereinafter referred to as 2009 MODU Code) and are included for reference purposes only. Additional definitions for offshore units are also given. Where applicable, reference to these definitions may be used in other Parts of these Rules.

1.1.6 For units containing drilling facilities, reference should be made to the requirements of the 2009 MODU Code and the requirements of Pt 3, Ch 7 for fire safety and escape and evacuation facilities.

1.1.7 Installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities are, in general, to comply with the requirements of Pt 11, Ch 11. It should be noted that Pt 11, Ch 11 of these Rules and Regulations reflects the requirements of the IMO *International Code for the Construction and Equipment of Ships carrying Liquefied Gases in Bulk* (IGC Code) and the associated Lloyd's Register's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

1.2 Submission of documentation

1.2.1 The requirements for submissions of documentation are given in 1.2.7 to 1.2.10, which are to be complied with where applicable.

1.2.2 Additional requirements with respect to unit types as indicated in this Section should also be complied with, as applicable, as in 1.2.3 to 1.2.10.

1.2.3 In addition to the requirements of Chapter 1 of these Rules, when Lloyd's Register (LR) is authorised to carry out approvals of fire protection, detection and extinction arrangements on behalf of a National Administration or the requirements of Pt 1, Ch 2,1.1.13 of these Rules are applicable, the plans and documents detailed below and required by 1.2.7, 1.2.8, 1.2.9 and 1.2.10 are to be submitted for approval, together with all additional relevant information, such as the intended function of the unit, the gross tonnage and the power of machinery.

1.2.4 The requirements for active and passive type fire protection systems are to be clearly defined within the unit's 'Fire and Explosion Evaluation' (FEE) report*, see* 2.4, and the requirements for means of escape, evacuation and rescue are to be clearly defined within the unit's 'Escape, Evacuation and Rescue Assessment' (EERA), *see* 4.1.2. Both reports are to be submitted for acceptance and in conjunction with the plans required below.

1.2.5 In the case of units with production and process plant, the FEE Report required by 1.2.4, which is also supporting the preparation and appraisal of information required in 1.2.8, 1.2.9 and 1.2.10, and the information required by 1.2.7, are to be submitted for review with full details of the water deluge system and/or water monitor system as required by 3.4.

1.2.6 For units with production and process plant, plans of escape routes with details of their protection are to be submitted for acceptance as required by 1.2.7.

1.2.7 For fire protection, the following plans and documents are to be submitted:

- A general arrangement plan showing escape routes, stairways and fire compartmentation bulkheads and decks, including machinery spaces, control stations, accommodation and service spaces, corridor bulkheads and stairway enclosures.
- A ventilation plan showing the ducts and any dampers in them, and the position of the controls for stopping the system.
- A plan showing the automatic fire detection and fire alarm system.
- A plan showing the location and arrangement of the emergency stop for the oil fuel unit pumps and for closing the valves on the pipes from oil fuel tanks.
- A plan showing the details of the construction of the fire protection bulkheads, decks and deck heads and the particulars of any surface laminates incorporated in them.
- Copies of the Certificates of Approval by National Authorities in respect of all 'A' and 'B' Class fire divisions, non-combustible materials and materials having low flame-spread characteristics, etc., which are intended to be used.
- A general arrangement plan showing the purpose of each room or compartment and the fire classification of the bulkheads, decks, deck heads and doors of the accommodation and service spaces, control rooms and machinery compartments.
- A plan showing the construction of the fire doors.
- A plan showing any proposed remote control system for closing doors.
- A plan showing any proposed water sprinkler system.
- A plan showing the location and arrangement of the emergency stop for the oil fuel unit pumps and for closing valves on the pipes from oil fuel tanks.
- A plan of any proposed gas detection and alarm system.

1.2.8 For fire-extinguishing, the following plans and particulars are to be submitted:

- A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials and the cross-connections to any other system.
- A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.
- A general arrangement plan showing the disposition of all the fire-fighting equipment, including the water fire main, all fixed fire-extinguishing systems, the disposition of all portable and non-portable extinguishers and the types used and the position and details of the fireman's outfits.
- A plan showing the layout and construction of hydrants, hoses and nozzles including their material and type and the international shore connections.

1.2.9 For fire-control, general arrangement plans are to be submitted:

(a) showing clearly for each deck:
  - The control stations;
  - The various fire sections enclosed by 'H' Class divisions, *see* 2.6.2;
  - The various fire sections enclosed by 'A' Class divisions, *see* 2.6.1; and
  - The fire sections enclosed by 'B' Class divisions, *see* 2.6.3;

(b) together with particulars of the:
  - Fire alarms;
  - Detecting systems;
  - Sprinkler/deluge systems (if any);
  - Fire-extinguishing appliances;
  - Means of access to different compartments, decks, etc.; and
  - Ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each fire section.

1.2.10 The general arrangement plans, as required by 1.2.9, are to be permanently exhibited in all units, for the guidance of those on board:

(a) Alternatively, the aforementioned details may be set out in a booklet, a copy of which is to be supplied to each responsible person, and one copy at all times is to be kept up to date, any alterations being recorded thereon as soon as practicable.

(b) All descriptions in such plans and booklets are to be in the official language of the Flag State. If the language is neither English nor French, a translation into one of those languages is to be included.

(c) In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

■ *Section 2* **Definitions**

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an acceptable test procedure (*see* IMO 2010 *International Code for Application of Fire Test Procedures, 2010*, hereinafter referred to as 2010 FTP Code). Any other material is a 'combustible material'.

2.1.2 **Steel or other equivalent material**. Where the words 'steel or other equivalent material' occur, 'equivalent material' means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g., aluminium with appropriate insulation).

2.2 Fire test

2.2.1 A **standard fire test** is one in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The specimen is to have an exposed surface of not less than 4,65 m^2 and height (or length of deck) of 2,44 m resembling as closely as possible the intended construction and including where appropriate at least one joint. The standard time-temperature curve is defined by a smooth curve drawn through the following temperature points measured above the initial furnace temperature:

at the end of the first 5 minutes	576°C
at the end of the first 10 minutes	679°C
at the end of the first 15 minutes	738°C
at the end of the first 30 minutes	841°C
at the end of the first 60 minutes	945°C.

2.2.2 A hydrocarbon fire test is one in which the specimens defined for a standard fire test are exposed in a test furnace to temperatures corresponding approximately to a time temperature curve relating to, and defined by, a smooth curve drawn through the following temperature points measured above the initial furnace temperature:

at the end of the first 3 minutes	880°C
at the end of the first 5 minutes	945°C
at the end of the first 10 minutes	1032°C
at the end of the first 15 minutes	1071°C
at the end of the first 30 minutes	1098°C
at the end of the first 60 minutes	1100°C.

2.2.3 A **jet-fire test** is used to determine how effective the passive fire protection materials are in withstanding an actual jet fire. Reference should be made to ISO 22899-1 with regard to jet-fire testing arrangements and defined jet-fire ratings.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by an acceptable test procedure (*see* IMO 2010 *International Code for Application of Fire Test Procedures, 2010*, hereinafter referred to as 2010 FTP Code).

2.4 Fire and Explosion Evaluation (FEE)

2.4.1 The FEE is an assessment of the potential fire loadings and blast pressures, based on the specific hazards associated with the general layout of the unit, production and process activities and operational constraints.

2.4.2 These Rules allow for the dimensioning of explosion loads to be based on probabilistic risk assessment techniques. A methodology to establish risk-based explosion loads based on such a probabilistic approach is given in LR's *Guidelines for the Calculation of Probabilistic Explosion Loads*.

2.5 Temporary refuge

2.5.1 This is a designated area that is to provide adequate facilities to protect the personnel from fire, explosion and associated hazards during the period for which they may need to remain on a unit following an uncontrolled incident, and for enabling their evacuation, escape and rescue. It is also to provide adequate facilities for monitoring and control of any major incident.

2.6 Fire divisions, spaces and equipment

2.6.1 **'A' Class divisions** are those divisions formed by bulkheads and decks which comply with the following:

(a) They are to be constructed of steel or other equivalent material.
(b) They are to be suitably stiffened.
(c) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test.
(d) They are to be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A–60'	60 minutes
Class 'A–30'	30 minutes
Class 'A–15'	15 minutes
Class 'A–0'	0 minutes.

(e) A test of a prototype bulkhead or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

Such divisions may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of SOLAS Ch. II-2, Reg. 5.3.2.

2.6.2 **'H' Class divisions** are those divisions formed by fire walls and decks which comply with the construction and integrity requirements for 'A' Class divisions, 2.6.1(a) and (b) and with the following:

(a) They are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour hydrocarbon fire test. (Note that some administrations may require the 'H' Class division integrity to be maintained for 120 minutes).
(b) They are to be insulated with approved non-combustible materials, such that the average temperature, on the unexposed side, when exposed to a hydrocarbon fire test, will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 180°C above the original temperature within the time listed below:

Class 'H-120'	120 minutes
Class 'H-60'	60 minutes
Class 'H-0'	0 minutes.

(c) A test of a prototype fire wall or deck may be required to ensure that it meets the above requirements for integrity and temperature rise.

2.6.3 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings which comply with the following:

(a) They are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test.

(b) They are to have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:
Class 'B–15' 15 minutes
Class 'B–0' 0 minutes

(c) They are to be constructed of approved non-combustible materials and all materials entering into the construction and erection of 'B' Class divisions are to be non-combustible.

(d) A test of a prototype division may be required to ensure that it meets the above requirements for integrity and temperature rise.

Such divisions may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of SOLAS Ch. II-2, Reg. 5.3.2.

2.6.4 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame, nor limitations relative to the temperature rise. Such divisions may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of SOLAS Ch. II-2, Reg. 5.3.2.

2.6.5 **Continuous 'B' Class ceilings or linings** are those 'B' Class ceilings or linings which terminate only at an 'A' or 'B' Class division. Such linings and ceilings may be faced with combustible materials, facings, mouldings, decorations and veneers, provided those are in accordance with the requirements of SOLAS Ch. II-2, Reg. 5.3.2.

2.6.6 **Machinery spaces of Category 'A'** are those spaces and trunks to such spaces which contain:

(a) Internal combustion machinery used for main propulsion; or

(b) Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

(c) Any oil-fired boiler or oil fuel unit.

2.6.7 **Machinery spaces** are all machinery spaces of Category 'A' and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

2.6.8 **Control stations** are those spaces in which the unit's radio or main navigating equipment is located or where the fire-control equipment or the dynamic positioning control system is centralised or process control equipment or where a fire-extinguishing system serving various locations is situated or, in the case of column-stabilised units, a centralised ballast control station is situated.

2.6.9 For definitions and categories of hazardous areas including 'enclosed' and 'semi-enclosed' spaces, *see* Ch 2,1.2.

2.6.10 **Drilling and process plant and industrial machinery and components** are the machinery and components which are used in connection with the operation of drilling, production and process systems.

2.6.11 **Working spaces** are those open or enclosed spaces containing equipment and processes which are not included in 2.6.6 or 2.6.7.

2.6.12 **Accommodation spaces** are those used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces. 'Public spaces' are those portions of the accommodation which are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

2.6.13 **Service spaces** are those used for galleys, pantries containing cooking appliances, lockers and storerooms, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

2.6.14 **Oil fuel unit** is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar.

2.6.15 **Crude oil** is any oil occurring naturally in the earth whether or not treated to render it suitable for transportation and includes:

(a) Crude oil from which certain distillate fractions may have been removed; and

(b) Crude oil to which certain distillate fractions may have been added.

2.6.16 **Storage spaces** are spaces used for bulk storage and trunks to such spaces, e.g., crude oil storage tanks on oil storage units.

■ *Section 3*
Additional requirements for units with production and process plant

3.1 General requirements for fire-water mains and pumps

3.1.1 Each unit is to be provided with a pressurised wet pipe fire main so equipped and arranged such that water for fire-fighting purposes can be supplied to any part of the unit. The fire main is to be:

(a) Connected to at least two independent fire pumping units, adequately segregated such that a single incident will not compromise the required fire-water supply, as defined in the unit's FEE Report. Each pumping unit is to be capable of providing sufficient fire-water to satisfy the maximum credible fire-water demand.
(b) Designed to deliver the pressure and flow requirements for the simultaneous operation of water-based active fire protection systems (deluge waterspray, monitors, hoses, etc.) sufficient to meet the requirements of these systems as defined in the FEE Report. This is typically to be the single largest credible fire area (where deluge/ waterspray systems are installed), plus any anticipated manual fire fighting demand (monitors/hose streams).
(c) Where required in the FEE Report, the total fire pumping capability is also to cater for fire escalating to adjacent areas, i.e., typically where suitable fire divisional barriers do not exist.
(d) Capable of delivering at least one jet simultaneously from each of any two fire hydrants, hoses and 19 mm nozzles, while maintaining a minimum pressure of 3,5 bar at any hydrant. In addition, where a foam system is provided for protection of the helicopter deck and is served by the fire main, a pressure of 7 bar at the foam installation is to be capable of being simultaneously maintained.

3.1.2 The arrangements of the pumps, sea suctions and sources of power are to be such as to ensure that a fire in any one space would not put more than one required pumping unit out of action.

3.1.3 Suitable provision is to be made for the automatic start-up of the fire pumps, when any fire-fighting appliance supplied with water from the fire main is operated. Provision is also to be made for the start-up of the pumps locally and remotely from a continuously manned space or fire-control station. Once activated the pumps are to be capable of continuous unattended operation for at least 18 hours.

3.2 Fire mains

3.2.1 The diameter of any fire-water main and individual service pipes is to be sufficient for the effective distribution of the maximum required discharge from the required pumps operating simultaneously.

3.2.2 With the required pumps operating simultaneously, the pressure maintained in a fire-water main is to be adequate for the safe and efficient operation of all equipment supplied therefrom. The arrangements are to be such that the hand-held fire-fighting equipment supplied from the main may be safely used by one person.

3.2.3 Where practicable, fire-water mains are to be routed clear of hazardous areas and be arranged in such a manner as to make maximum use of any thermal shielding or physical protection afforded by the structure of the offshore installation or unit.

3.2.4 Fire-water mains are to be provided with isolating valves, located so as to permit optimum utilisation of the main in the event of physical damage to any part of the main.

3.2.5 Fire-water mains are not to have connections other than those necessary for fire-fighting purposes.

3.2.6 Where applicable, all practicable precautions consistent with having water readily available are to be taken to protect the fire main against freezing.

3.2.7 Materials readily rendered ineffective by heat, are not to be used for fire-water mains unless adequately protected. The pipes and hydrants are to be so placed that the fire hoses may be easily coupled to them.

3.3 Fire pumps

3.3.1 Any diesel-driven power source is to be capable of being readily started in its cold condition down to a temperature of 0°C, except where agreed otherwise with LR. If this is impracticable, or if lower temperatures are likely to be encountered, consideration will be given to the provision and maintenance of heating arrangements, so that ready starting will be assured. The engine is to be equipped with an approved starting device (e.g., starting battery), independent hydraulic system, or independent starting air system, having a capacity sufficient for at least six starts of the emergency fire pump within a 30 minute period with at least two starts within the first 10 minutes.

3.3.2 Any service fuel tank is to contain sufficient fuel to enable the pump to run on full load for at least 18 hours.

3.3.3 Under both normal and emergency conditions any compartment in which a pump unit is located is to be accessible, properly illuminated and efficiently ventilated.

3.3.4 Every centrifugal pump which is connected to a fire water main is to be fitted with a non-return valve.

3.3.5 Relief valves are to be provided in conjunction with all pumps connected to a fire-water main if the pumps are capable of developing a pressure exceeding the design pressure of the main, hydrants and hoses or other fire-fighting equipment connected to the main. Such valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire-water main system.

3.3.6 Means are to be provided for testing the output capacity of each fire pumping unit, in accordance with NFPA (20) or an equivalent Standard.

3.3.7 The provision of surge relief devices is also to be considered at the fire pumps, to prevent over-pressurisation of the mains on fire pump start-up. Such devices are to reset automatically once the excess pressure has been relieved.

3.3.8 The fire-water pump stop should be local only. Except during testing, any alarms from pump-monitoring systems should not automatically stop a running fire pump with the exception of engine overspeed for fire-water pump engine drive units. Fire detection at the fire-water pump should not stop the pump or inhibit the start of the fire-water pump driver. Confirmed hydrocarbon detection in the air inlet of the driver should inhibit the pump start but should not trip a running fire-water pump.

3.3.9 With reference to 3.3.8, the design of the fire-water pump drive system shall ensure, so far as practical, that the fire-water pump drive set does not constitute an ignition source for potential hydrocarbon gas which may migrate to the pump drive enclosure on a hydrocarbon release incident. As such, the fire-water pump drives should be located in a non-hazardous area of the installation or unit and housed in a non-hazardous enclosure with ventilation designed to be maintained at an overpressure of at least 50 Pa in relation to adjacent external spaces. The fire-water pump drive enclosure is to be constructed with suitable fire-rated and gastight barriers, suitable fire-rated and gastight doors, and suitable fire-rated and gas-rated dampers. The design of the fire-water pump drive is to be such that, on gas detection on the enclosure ventilation air intakes, the drive is capable of continued operation with the enclosure ventilation shut down, ventilation fire and gas dampers closed and all entrances to the enclosure closed.

3.3.10 The installation design should incorporate a suitable allowance for fire-water pump redundancy. This redundancy is to allow for failure of a fire-water pump on demand or loss of a fire-water pump for maintenance without incurring potential lost production on the installation due to the loss of fire-water supply. Permanently manned hydrocarbon installations typically have two 100 per cent or three 50 per cent fire-water pumps designed to meet the installation's defined largest credible fire-water demand scenario (i.e., the installation's 100 per cent fire-water demand). However, other configurations of fire-water pump supply redundancy may be acceptable for an installation, subject to suitable demonstration (for example, normally unmanned installations often do not have any dedicated fire-water pumps).

3.4 Water deluge systems, water monitors and foam systems

3.4.1 The topside area of each installation or unit is to be provided with a water deluge system and/or water monitor system by means of which any part of the installation or unit containing equipment used for storing, conveying or processing hydrocarbon resources (other than fuels for use on the unit) can be protected in the event of fire. Areas containing equipment requiring water protection include the following:

- Any drilling facilities including the BOP.
- Areas containing equipment, (including piping) through which hydrocarbons will flow during well test operations.
- Crude oil and gas manifolds/piping (not fuel gas), including piping routed over bridges between platforms.
- Crude oil pumps.
- Crude oil storage vessels.
- De-aeration/filtration equipment (if using gas).
- Emergency shut-down valves.
- Flare knockout drums.
- Gas compressors.
- Gas liquids/condensate storage vessels.
- Glycol regeneration plant.
- Liquefaction plant.
- Pig launchers/receivers.
- Process pressure vessels.
- Process separation equipment.
- Riser connections.
- Swivel stack areas.
- Turret areas.

3.4.2 Water deluge systems and water monitors are to be connected to a continuously pressurised water main supplied by at least two pumps, capable, with any one pump out of action, of maintaining a supply of water at a pressure sufficient to enable the system or monitors to operate at the required discharge rates to meet the water demand of the largest single area requiring protection in accordance with the FEE.

3.4.3 The quantity of water supplied to any part of the production and process plant facility is to be at least sufficient to provide exposure protection to the relevant equipment within that part, and where appropriate, local principal load-bearing structural members. 'Exposure protection' means the application of water spray to equipment or structural members to limit absorption of heat to a level which will reduce the possibility of failure.

3.4.4 Generally, the minimum water application rate is to be not less than 10 litres/minute over each square metre of exposed surface area requiring protection within the appropriate reference area. Other water application rates in accordance with a recognised Standard or Code which meets the requirements of 3.2.1 will be considered. The defined water application rates should be established based on a recognised National or International Standard (*see* ISO 13702 or IMO FSS Code). A reference area is a horizontal area bounded completely by:

(a) Vertical 'A' or 'H' Class divisions; or
(b) The outboard extremities of the unit; or
(c) A combination of (a) or (b).

3.4.5 Each part requiring water protection is to be provided with a primary means of application, which may be:

(a) A fixed system of piping fitted with suitable spray nozzles; or
(b) Water monitors; or
(c) A combination of (a) and (b).

NOTE
Water monitors may only be used for the protection of equipment sited in essentially open areas.

3.4.6 The layout of piping and nozzles within each reference area is to be such that all parts requiring protection are exposed to the direct impingement of water spray. The piping system may be sub-divided within each reference area in accordance with the disposition of equipment and structure.

(a) Spray nozzles are to be of the open type and fitted with deflector plates or equivalent devices capable of reducing the water discharge to a suitable droplet size. The relative location and orientation of individual nozzles is to be in keeping with their established discharge characteristics.
(b) The water pressure available at the inlet to a system or an individual section is to be sufficient to ensure efficient operation of all nozzles in the system or section.

3.4.7 Water monitors may be operated either remotely or locally. Each monitor arranged solely for local operation is to be:

- Provided with an access route which is remote from the part requiring protection; and
- Sited so as to afford maximum protection to the Operator from the effects of radiant heat.

Each monitor is to have sufficient movement in the horizontal and vertical planes to permit the monitor to be brought to bear on any part protected by it. Means are to be provided to lock the monitor in any position. Each monitor is to be capable of discharging under jet and spray conditions.

3.4.8 Any additional requirements for foam type fire protection systems to the topsides process modules and associated plant are to be evaluated within the unit's FEE Report. The specific requirements for foam systems are to be designed to provide extinguishing capabilities in areas where hydrocarbon pool fires may occur. Consideration shall also be given to bunding/drainage arrangements in these areas to ensure that system functionality is not compromised due to lack of hydrocarbon containment.

3.4.9 With regard to the performance requirements for foam systems (concentration levels, discharge time, method of induction, etc.), particular attention is to be given to the design criteria outlined in NFPA 16 or reference is to be made to an acceptable equivalent standard.

3.4.10 With reference to the above requirements for water deluge and water monitor coverage, it may be possible to utilise passive fire protection in place of fire-water cover over certain facilities dependent upon the finding of the FEE, *see* 3.6.

3.5 Hydrants, hoses and nozzles

3.5.1 The number and position of the hydrants are to be such that at least two jets of water, not emanating from the same hydrant, one of which is to be from a single length of fire hose, may reach any part of the installation or unit normally accessible to those on board. A hose is to be provided for every hydrant.

3.5.2 A cock or valve is to be fitted to serve each fire hose so that any fire hose may be removed while the fire pumps are operational.

3.5.3 Fire hoses are to be of type approved material and be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length in general is not to exceed 18 m. Every fire hose is to be provided with a nozzle and the necessary couplings. Fire hoses together with any necessary fittings and tools are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

3.5.4 Standard nozzle sizes are to be 12 mm, 16 mm and 19 mm or as near thereto as possible. Larger diameter nozzles may be permitted if required as a result of special considerations.

3.5.5 For exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure specified in 3.1.1(d) provided that a nozzle size greater than 19 mm need not be used.

3.5.6 The jet throw at any nozzle is to be about 12 m.

3.5.7 All nozzles are to be of an approved dual purpose type (i.e., spray/jet type) incorporating a shut-off.

3.5.8 Mobile Offshore drilling units should be provided with at least one international shore connection complying with SOLAS Regulation II-2/10.2.1.7 and the FSS Code. Facilities should be available enabling such a connection to be used on any side of the unit.

3.6 Passive fire protection

3.6.1 As outlined in 1.2.1, 1.2.2 and 3.4.10, the additional requirements for passive type fire protection systems to the topsides process modules and associated plant are to be evaluated within the unit's FEE Report. The specific requirements for passive fire protection (PFP) systems are to be designed to provide adequate hydrocarbon containment to prevent escalation and enable safe evacuation of personnel to the 'Temporary Refuge'.

3.6.2 With regard to the performance requirements for PFP systems, particular attention is to be given to the potential thermal and erosive effects of hydrocarbon jet-fires in the initial phase of a topsides incident. Consideration is also to be given to the ongoing thermal effects from pool fires. The duration of these events is to be examined in the project FEE in conjunction with the process system blowdown capabilities.

3.7 Other fixed fire-extinguishing systems

3.7.1 Where included and assessed in the FEE Report (*see* 1.2.4) additional consideration will be given to the installation of other fixed fire-extinguishing systems (which may include, but may not be limited to, Fixed Pressure Water Spraying and Water-Mist fire-extinguishing systems, High Expansion Foam systems, Clean Agent fire-extinguishing systems) within internal machinery spaces, accommodation and service spaces, such as cabins and low risk areas. Specific functionality requirements for these systems should be evaluated and clearly defined within the FEE Report.

3.7.2 With regard to the performance requirements for Fixed Pressure Water Spraying and Water-Mist fire-extinguishing systems, particular attention should be given to the requirements of FSS Code Chapter 7 (Machinery Spaces) and Chapter 8 (Accommodation Areas) respectively, and of testing standards referred to therein. Reference can also be made to an acceptable equivalent standard (such as NFPA 750) for project-specific applications.

3.8 Installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities

3.8.1 Installations with liquefied gas storage in bulk and/or vapour discharge and loading manifolds/facilities are, in general, to comply with the requirements of Chapter 11 of the IMO *International Code for the construction and Equipment of Ships carrying Liquefied Gases in Bulk* (IGC Code) and Chapter 11 of the associated LR's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*. However, specific reference is to be made to the requirement stipulated within Pt 11, Ch 11.

■ *Section 4*
Means of escape, evacuation and rescue

4.1 General requirements

4.1.1 For the general requirements for means of escape, *see* SOLAS Ch II-2, Part D, Ch III and IMO *Life-Saving Appliances (LSA) Code*. For units with drilling facilities, *see also* the requirements of 2009 MODU Code Chapter 9.4 and Ch 10.

4.1.2 Escape ways on units with production and process plant are to be adequately protected against potential fire loadings emanating from the topside plant and production facilities. The following objectives are to be considered when evaluating the unit's requirements for escape, evacuation and rescue, as also required to be detailed in the Escape, Evacuation and Rescue Assessment (EERA), referred to in 1.2.4:

- To maintain the safety of all personnel when they move to another location to avoid the effects of a hazardous event.
- To provide a refuge on the unit for as long as required to enable a controlled evacuation of the unit.
- To facilitate recovery of injured personnel.
- To ensure safe abandonment of the installation or unit.

4.1.3 Where sufficient physical barriers do not exist, escape ways are to be protected by way of active (deluge cooling) or passive (fire screen) type systems.

4.1.4 Escape route widths are to be considered with relation to the number of personnel and individual occupancy of all topsides process and turret areas. Escape routes are to be provided to enable all personnel to evacuate an area safely, when they are directly affected by an incident.

4.1.5 In general, main escape ways from major process and production areas are to have a minimum clear width of 1000 mm, to enable the safe passage of potentially injured personnel (i.e., stretcher evacuees).

■ *Section 5*
Deckhouses and superstructures used for accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter'

5.1 Boundary bulkheads

5.1.1 Particular consideration is to be given to the potential effects of fire and blast, as determined in the unit's 'Fire and Explosion Evaluation' (FEE) report required by 1.2.4, impinging on exposed boundary bulkheads of accommodation spaces, 'temporary refuge' or 'alternative/secondary refuge or shelter'. Where boundary bulkheads can be subjected to blast loading the scantlings are to comply with Pt 4, Ch 3,4.16.8 and Ch 15,1.8.

5.2 Safety critical requirements for enclosed spaces

5.2.1 In addition to the requirements of Ch 2,4, enclosed spaces of deckhouses and superstructures used for accommodation and/or 'temporary refuge' or 'alternative/secondary refuge or shelter' are to be at an overpressure relative to the external area to prevent the potential ingress of smoke and hazardous gases, in the event of a major topsides incident.

5.2.2 With reference to 5.2.1, the design of the accommodation, 'temporary refuge' and 'alternative/secondary refuge or shelter' is to be such that their enclosures are supplied with a ventilation system designed to maintain an overpressure of at least 50 Pa in relation to adjacent external spaces. The ventilation air intakes to any such enclosure are to be equipped with suitable hydrocarbon gas, smoke and/or toxic gas detection, dependent upon the credible risks associated with the installation or unit. The enclosures are to be constructed with suitable fire-rated and gastight barriers, suitable fire-rated and gastight doors, and suitable fire-rated and gas-rated dampers. The design of the enclosures is to be such that, on hydrocarbon gas, smoke and/or toxic gas detection at the enclosure ventilation air intakes, dependent upon the credible risks associated with the installation or unit, the enclosure ventilation system will shut down and all ventilation fire and gas dampers will close in order to mitigate against potential hydrocarbon gas, smoke and/or toxic gas entering the accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter'.

Dependent upon the design of the accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter' ventilation system, consideration should be given to retain a recirculation ventilation system or an alternative air supply to such enclosures on hydrocarbon gas, smoke and or/toxic gas detection at the enclosure ventilation air intakes. However, it should be ensured that the integrity of the enclosures is not impaired by continued operation of any ventilation system in this scenario.

5.2.3 An endurance period for the 'temporary refuge' should be defined in accordance with the escape, evacuation and rescue philosophy for the installation or unit, and appropriate facilities for life support within them should be provided, which should include, but may not be limited to, the following:

- Lighting.
- Means of internal and external communication.
- Means of controlling and monitoring the installation or unit safety systems'.

Design of the 'temporary refuge' has also to ensure an appropriate environment for personnel mustering at the location, and for that purpose consideration should be given to criteria such as oxygen depletion, CO_2 build-up and temperature build-up. Information relevant to any such system can be provided as part of the 'Escape, Evacuation and Rescue Assessment' (EERA) required by 1.2.4.

5.2.4 With reference to 5.2.2, the design of the accommodation 'temporary refuge' or 'alternative/secondary refuge or shelter' enclosure is to include a suitable air leakage rate to mitigate against any potential hydrocarbon gas, smoke and/or toxic gas impairment on isolation of the accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter' enclosure ventilation. The air leakage rate should be based on the required endurance period of the accommodation, 'temporary refuge' or 'alternative/secondary refuge or shelter' in any potential credible hydrocarbon gas, smoke and/or toxic gas incident associated with the installation or unit.

5.2.5 When the escape, evacuation and rescue philosophy for the installation or unit, or the 'Escape, Evacuation and Rescue Assessment' (EERA), referred to in 1.2.4, require an alternative or a secondary refuge/shelter, it should be demonstrated that any such refuge/shelter provides appropriate levels of protection and evacuation facilities (including personal protective equipment and personal lifesaving appliances, as applicable) for personnel mustering at those locations, as defined in the EERA.

5.3 Access doors

5.3.1 Access doors to spaces referred in 5.2.1 are to be fitted with self-closing gastight doors that open outwards from the enclosed space. Special consideration will be given to spaces which are protected by mechanically ventilated air locks, *see also* Ch 2,4.

Rules and Regulations for the Classification of Offshore Units

Part 8
Corrosion Control

July 2014

Lloyd's Register

Chapter Contents

Contents

Section 1 Corrosion protection

1.1 Application

1.1.1 The requirements cover the corrosion protection of offshore units of the general types defined in Pt 1, Ch 2,2, *see also* Pt 3, Ch 1. Requirements are also given for riser systems, *see* Section 2.

1.1.2 All structural steel work is to be suitably protected against loss of integrity due to the effects of corrosion. In general, suitable protective systems may include coatings, metallic claddings, cathodic protection, corrosion allowances or other approved methods. Combinations of methods may be used when agreed by Lloyd's Register (LR). Consideration should be paid to the design life and the maintainability of the surfaces in the design of the protected systems.

1.1.3 The basic Rule scantlings of the external submerged steel structure of units which are derived from Part 4 assume that a cathodic protection system will be effective and in use continually. Unless agreed otherwise with LR no corrosion allowance will be included in the approved scantlings, *see* Pt 3, Ch 1,5.

1.2 Zone definitions

1.2.1 The type of protection of the steelwork is to be suitable for the structural location of the unit and for this purpose the steel structure is to be considered in terms of zones.

1.2.2 **Submerged zone**. That part of the external structure below the maximum design operating draught.

1.2.3 **Boot topping zone**. That part of the external structure between the maximum design operating draught and the light design operating draught. For column-stabilised units, *see* Table 1.1.1.

1.2.4 **Splash zone**. That part of the external structure above the boot topping zone subject to wet and dry conditions.

1.2.5 **Atmospheric zone**. That part of the external structure above the splash zone.

1.2.6 **Internal zones**. Ballast tanks, liquid storage tanks, and other compartments.

1.3 External zone protection

1.3.1 The minimum requirements for corrosion protection of the external steelwork of offshore units is given in Table 1.1.1.

1.3.2 The structural steelwork in the boot topping and splash zones is normally to be protected by suitable coatings but consideration may be given to the following:
(a) Extra steel in excess of the Rule requirements.
(b) Metallic cladding where appropriate.

1.3.3 The structural steelwork in the atmospheric zone is to be protected by suitable coatings.

1.3.4 The structural steelwork in the submerged zone is to be protected by an approved means of cathodic protection using sacrificial anodes or an impressed current system, except where noted otherwise in Table 1.1.1. High resistance coatings may be required or used in conjunction with a cathodic protection system but they will not be accepted in lieu except where noted in Table 1.1.1. An alternative means of protection such as increased scantlings may be considered in special areas.

1.4 Internal zones

1.4.1 Ballast tanks shall be protected from corrosion by a combination of anti-corrosion coatings and cathodic protection.

1.4.2 At the time of new construction, all salt-water ballast tanks shall have an efficient protective coating, epoxy or equivalent, applied in accordance with the manufacturer's recommendations. The durability of the coatings could affect the frequency of survey of the tanks and light coloured coatings would assist in improving the effectiveness of subsequent surveys. It is therefore recommended that this be taken into account by those agreeing the specification for the coatings and their application.

1.4.3 Storage tanks and other compartments require corrosion protection where the storage product may be corrosive. Particular attention should be paid to the likelihood of water in the bottom of hydrocarbon storage tanks and the effects of bacterial induced corrosion. Suitable protective measures may include coatings, corrosion inhibitors together with biocides.

1.4.4 In deep draught caisson units and other units with combined oil storage and ballast tanks which remain full during the service life of the unit, special consideration will be given to the requirement for internal corrosion protection of the tanks. In general, the minimum Rule scantlings of tanks as required by Pt 4, Ch 6,7 are to be suitably increased.

Table 1.1.1 Minimum corrosion protection requirements for external structural steelwork

Unit type	Corrosion protection required and area		
	Zone	Structural steelwork	Method of protection required
Column-stabilised units and tension-leg units	Submerged zone	Columns, lower hulls and bracings	Cathodic protection and coatings, *see* Notes 1 and 5
	Boot topping and splash zones, *see* Note 2	Columns, lower hulls and bracings	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Self-elevating units	Transit condition: Submerged, boot topping and splash zones	Main hull	Coatings only
	Elevated condition: Submerged zone	Legs, footings and mats	Cathodic protection and coatings, *see* Note 5
	Boot topping and splash zones, *see* Note 4	Legs	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Ship units and other surface type units	Submerged zone	Main hull	Cathodic protection and coatings, *see* Note 1
	Boot topping and splash zones	Main hull	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Deep draught caisson units and buoy units	Submerged zone	Main hull	Cathodic protection and coatings, *see* Note 1
	Boot topping and splash zones	Main hull	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only
Mooring towers	Submerged zone	Main hull	Cathodic protection and coatings, *see* Note 1
	Boot topping and splash zones, *see* Note 3	Main hull	Coatings
	Atmospheric zone	All structure above the splash zone	Coatings only

NOTES

1. For the assignment of the In-Water Survey notation **OIWS**, corrosion protection by both cathodic protection and high resistance paint coatings is required.
2. For column-stabilised units the boot topping zone is to be taken as that part of the external structure between the maximum design operating draught and the transit draught.
3. For mooring towers the boot topping zone is to extend between the lowest and highest atmospheric tides at the operating location.
4. For self-elevating units, in the elevated position, the boot topping zone is to extend between the lowest and highest atmospheric tides at the operation location.
5. For mobile offshore units, if In-water Survey notation, **OIWS**, is not assigned, coatings may be omitted except in the boot topping zone, *see* Note 2.

1.5 Bimetallic connections

1.5.1 Where bimetallic connections are made in the structure, suitable measures are to be incorporated to preclude galvanic corrosion. Details are to be submitted for approval on the structural plans required in Pt 4, Ch 1,4. The combination of painting the less noble material and leaving the more noble material uncoated for an immersed bimetallic couple is not permitted.

1.6 Chain cables and wire ropes

1.6.1 Chain cables and wire ropes for positional mooring systems are to be protected from corrosion and the requirements of Pt 3, Ch 10 are to be complied with.

Section 2 Riser systems

2.1 General

2.1.1 Riser systems are to be suitably protected against corrosion. It is recommended that this be achieved using a coating combined with a cathodic protection system. Account should be taken of possible temperature effects. Other equivalent methods of protection will be considered.

2.1.2 The splash and boot topping zones of risers are to be specially considered. A corrosion allowance will be required in addition to any coatings. Risers in J-tubes, etc., will require separate assessment of protection.

2.1.3 Where the cathodic protection system is designed to compensate for loss of protective coating, the system should be based on an initial loss of coating of between 5 and 10 per cent. Due allowance should be made for further break-down during the service life.

2.2 External coatings

2.2.1 Paint or protective coatings are generally to be chosen in conjunction with the system of cathodic protection.

2.2.2 The performance of the coating materials used should be proven by previous service or by extensive and documented laboratory testing.

2.2.3 Preparation of the riser surface before coating is to comply with the approved specification relating to that material, *see* Ch 4,3.5.

2.3 Internal protection

2.3.1 The method of internal protection is to take into account the corrosivity, bacterial content, solids/abrasive content, flow characteristics and temperature and pressure.

2.3.2 Materials or systems (e.g., liners) are to be evaluated against the service nature of the product to be conveyed. Proprietary specifications and in-service history are to be submitted as required by LR.

2.3.3 Where internal protection is proposed by use of corrosion inhibitors, the properties, compatibility and effect on product conveyed are all to be documented and submitted.

2.4 Cathodic protection systems

2.4.1 Cathodic protection systems are to comply with the requirements of Chapter 2.

2.4.2 Measurements of potential are to be taken and any deficiencies corrected by the addition of extra sacrificial anodes.

2.4.3 Measurements are to be taken to confirm that there is no over-protection.

2.4.4 Stray currents from ships, other vessels or installations in the vicinity are to be evaluated and appropriate measures taken.

Section 3 Plans and information

3.1 Scope

3.1.1 In order that an assessment may be made of protection systems full details as outlined in this Section are to be submitted.

3.2 Cathodic protection systems

3.2.1 The following plans and information are to be submitted:

(a) A surface area breakdown for all areas to be protected including secondary steelwork and details of appurtenances.
(b) The resistivity of the sea water.
(c) All current densities used for design purposes.
(d) The type and location of any reference electrodes and their methods of attachment.
(e) Full details of any coatings used and the areas to which they are to be applied.
(f) Details of any electrical bonding.

3.3 Sacrificial anode systems

3.3.1 In addition to the information required by 3.2 the following plans and information are to be submitted:

(a) The design life of the system in years.
(b) Anode material and minimum design capacity of anode material, in Ah/kg.
(c) The dimensions of anodes including details of the insert and its location.
(d) The nett and gross weight of the anodes, in kg.
(e) The means of attachment.
(f) Plans showing the location of the anodes.
(g) Calculation of anodic resistance, as installed and when consumed to their design and utilisation factor, in ohms.
(h) Closed circuit potential of the anode material, in volts.
(j) Details of any computer modelling.
(k) The anode design utilisation factor.

3.4 Impressed current systems

3.4.1 In addition to the information required by 3.2, the following plans and information are to be submitted:

(a) The anode composition and where applicable the thickness of the plated surface, consumption and life data.
(b) Anode resistance, limiting potential and current output.
(c) Details of construction and attachment of anodes and reference electrodes.
(d) Size, shape and composition of any dielectric shields.
(e) Diagram of the wiring system used for the impressed current and monitoring systems including details of cable sizes, underwater joints, type of insulation and normal working current in circuits, and the capacity, type and make of the protected devices.
(f) Details of glands and size of steel conduits.
(g) Plans showing the locations of the anodes and reference electrodes.
(h) If the system is to be used in association with a coating system then a statement is to be supplied by the coating manufacturer that the coating is compatible with the impressed current cathodic protection system.

3.5 Coating systems

3.5.1 The following plans and information are to be submitted:

(a) Evidence that any primers used will have no deleterious effect on subsequent welding or on subsequent coatings.
(b) Details of the painting specification with regard to:
  (i) The generic type of the coating and conformation of its suitability for the intended environment;
  (ii) The methods to be used to prepare the surface before the coating is applied and the standard to be achieved. Reference should be made to established International or National Standards;
  (iii) The method of application of the coating; and
  (iv) The number of coats to be applied and the total dry film thickness.
(c) Details of the areas to be coated.

3.5.2 In addition to the information required by 3.5.1 the following may also be required:

(a) When a coating contains aluminium and is intended to be used on decks or in areas where flammable gases may accumulate, a statement from an independent laboratory confirming that appropriate tests have shown that the coating does not increase the incendive sparking hazard in the area to which it is to be applied.
(b) Where a coating is to be applied in accommodation spaces, machinery spaces and areas of similar fire risk, a statement that the coating is not formulated on a nitrocellulose or other highly flammable base and has low flame spread characteristics (complying to at least BS476: Part 7: Classification 2 or any other equivalent National Specification).

3.6 Inhibitors and biocides

3.6.1 Where it is proposed to use inhibitors, biocides, or other chemicals for the protection of storage tanks, full details, including compatibility with each other and evidence of satisfactory service experience or suitable laboratory test results or any other data to substantiate the suitability for the intended purpose are to be submitted for consideration.

■ *Section 1* General requirements

1.1 Objective

1.1.1 The cathodic protection system for the external submerged zone is to be designed for a period commensurate with the design life of the structure or the dry-docking interval and it should be capable of polarising the steelwork to a sufficient level in order to minimise corrosion.

1.1.2 This may be achieved using either sacrificial anodes or an impressed current system or a combination of both, *see* 3.2.1.

1.2 Electrical continuity

1.2.1 All parts of the structure should be electrically continuous and, where considered necessary, appropriate bonding straps should be fitted across such items as propellers, thrusters, rudders and legs, etc., and the joints of articulated structures are to be efficiently completed to the Surveyor's satisfaction.

1.2.2 Where bonding straps are not fitted, a supplementary cathodic protection system should be considered.

1.2.3 Particular attention to earthing and bonding is required in hazardous areas where flammable gases or vapours may be present, *see* Part 7.

To avoid dangerous sparking between metallic parts of structures, potential equalisation is always required for installations in Zone 1 and may be necessary for installations in Zone 2 areas; this is achieved by connecting all exposed and extraneous conductive parts to the equipotential bonding system. Notwithstanding this, cathodic protection installations are not to be connected to the equipotential bonding system unless the cathodic protection system is specifically designed for this purpose. *See* IEC 61892-7 Section 5.6.3.

Cathodically protected metallic parts are live extraneous conductive parts. If located in hazardous areas, they are to be considered potentially dangerous (especially if equipped with the impressed current method) despite their low negative potential.

No cathodic protection is to be provided for metallic parts in Zone 0 unless it is specially designed for this application. *See* IEC 61892-7 Section 5.6.6.

1.2.4 Consideration should be given to the influence of any connecting structures, such as risers and pipelines, on the efficiency of the cathodic protection system. A floating structure may be permanently or temporarily connected to another neighbouring structure. In this situation, the requirements of BS EN 13173 are to be met, including the taking of measurements to ensure that there are no deleterious effects of electrical stray current on the protected structure.

1.3 Criteria for cathodic protection

1.3.1 Cathodic protection systems are to comply with BS EN 13173 – *Cathodic protection for steel offshore floating structures* or BS EN 12495 – *Cathodic protection for fixed steel offshore structures*.

1.3.2 The cathodic protection system is to be capable of polarising the steelwork to potentials measured with respect to a silver/silver chloride/sea-water (Ag/AgCl) reference electrode to within the following ranges:
(a) –0,80 to –1,10 volts for aerobic conditions.
(b) –0,9 to –1,10 volts for anaerobic conditions.

1.3.3 Potentials more negative than –1,10 volts Ag/AgCl must be avoided in order to minimise any damage due to hydrogen absorption and reduction in the fatigue life. For steel with a tensile strength in excess of 700 N/mm^2 the maximum negative potential should be limited to –0,95 volt. But where the steel is prone to hydrogen assisted cracking the potential should not be more negative than –0,83 volt (Ag/AgCl reference cell).

1.3.4 High strength fastening materials should be avoided because of the possible effects of hydrogen, and the hardness of such bolting materials should be limited to a maximum of 300 Vickers Diamond Pyramid Number.

1.3.5 The potential for steels with surfaces operating above 25°C should be 1 mV more negative for each degree above 25°C.

1.3.6 For guidance on the design of sacrificial anode systems, *see* Ch 4,2.

■ *Section 2* Sacrificial anodes

2.1 General

2.1.1 Sacrificial anodes intended for installation on units are to be manufactured in accordance with the requirements of this Section.

2.1.2 Plans showing anode nominal dimensions, tolerances and fabrication details are to be submitted for approval prior to manufacture.

2.1.3 Approval for the manufacture of anodes is not required although the anodes should preferably be type approved in accordance with Lloyd's Register's (LR's) *List of Type Approval Equipment*.

2.1.4 The works should have a quality management system certified by a recognised third-party certification body. However, alternative arrangements may be accepted provided they ensure a consistent quality for the anodes.

2.2 Anode materials

2.2.1 The anode materials are to be approved alloys of zinc or aluminium with a closed-circuit potential of at least –1,00 volt (Ag/AgCl reference electrode). Magnesium-based anodes may be used for short-term temporary protection of materials not susceptible to hydrogen embrittlement, *see also* 2.13.12. Anode materials and anode designs specified in BS EN 13173 or BS EN 12495 are also permitted.

2.3 Steel insert preparation

2.3.1 The anode material is to be cast around a steel insert so designed as to retain the anode material even when it is consumed to its design utilisation factor.

2.3.2 The steel inserts are to have sufficient strength to withstand all external forces that they may normally encounter such as wave, wind, ice loading and operating conditions.

2.3.3 The anodes are to be sufficiently rigid to avoid vibration in the anode support.

2.3.4 The steel inserts are to be of weldable structural steel bar, section or pipe with a carbon equivalent not greater than 0,45 per cent determined using the following formula:

Carbon equivalent, $C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$

Rimming steel is not permitted.

2.3.5 Requirements for welded fabrication and non-destructive testing are to be in accordance with Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.3.6 The steel insert is to be degreased if necessary and blast cleaned to a standard equivalent to ISO 8501-1 Sa 2$^{1}/_{2}$ with a minimum surface profile of 50 μm. This standard of cleanliness is to be maintained up until the time of castings. For zinc anodes, blast cleaning may be followed by galvanising or by an approved zinc plating process.

2.4 Chemical composition

2.4.1 The chemical composition of the heat is to be determined prior to casting. No alloying additions are to be made following chemical analysis without further analysis. For heats greater than 1 tonne, a further sample is to be analysed at the end of the cast. All anodes cast are to comply with the approved specification.

2.5 Conditions of supply

2.5.1 Generally anodes are to be supplied in the as-cast condition although certain aluminium anodes may be heat treated in accordance with the approved specification.

2.5.2 Where heat treatment is carried out it is to be in properly constructed furnaces which are efficiently maintained and have adequate means for the control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature.

2.6 Anode identification

2.6.1 The manufacturer is to adopt a system of identification of the anodes to enable the material to be traced back to its original cast.

2.6.2 The anodes are to be clearly marked with the following:
(a) Name or initials of the anode manufacturer.
(b) Number and/or initials to identify the batch.
(c) Agreed identification mark for the anode material.

2.6.3 Where the anodes are heat treated they are also to be marked with the appropriate heat treatment batch number.

2.7 Anode inspection

2.7.1 All anodes are to be cleaned and adequately prepared for inspection. The surfaces are not to be hammered, peened or treated in any way which may obscure defects. However, any flash or other protrusions should be removed prior to inspection.

2.7.2 Anodes are to be inspected prior to the application of any coating which may be applied to the underside of the anode or to the exposed steelwork.

2.7.3 The surface should be free of any significant slag or dross or anything that may be considered detrimental to the satisfactory performance of the anodes.

2.7.4 Shrinkage depressions should not exceed the smaller of 10 per cent of the nominal depth of the anode or 50 per cent of the depth to the anode insert.

2.7.5 Cracks in the longitudinal direction are not acceptable. Small transverse cracks may be permitted provided:

(a) They are not more than 5 mm in width;
(b) They are within the section wholly supported by the steel insert;
(c) They do not extend around more than two faces or 180° of the anode circumference; and
(d) The Surveyor is satisfied that there has been no breakdown in Quality Control procedures.

2.7.6 Cold shuts or surface laps should not exceed a depth of 10 mm or extend over a total length equivalent to more than three times the width of the anode. All material is to be completely bonded to the bulk material.

2.8 Dimensions

2.8.1 The accuracy and verification of dimensions is the responsibility of the manufacturer unless otherwise agreed.

2.8.2 The diameter of cylindrical anodes should be within ±5 per cent of the nominal diameter.

2.8.3 For long slender anodes the following dimensions should apply:

(a) Mean length ±3 per cent of nominal length or ±25 mm, whichever is smaller.
(b) Mean width ±5 per cent of nominal width.
(c) Mean depth ±10 per cent of nominal depth.

2.8.4 The maximum deviation from straightness should not exceed two per cent of the length.

2.8.5 The steel insert should be within ±5 per cent of the nominal position in anode width and length and within 10 per cent of the nominal position in depth. Some anodes may have the insert close to one surface, in which case a closer tolerance may be more appropriate.

2.8.6 Except where previously agreed, the anode insert fixing dimensions are to be within ±1 per cent of the nominal dimensions or 15 mm, whichever is the smaller.

2.8.7 Anode nominal dimensions, tolerances and fabrication details are to be shown on manufacturing plans prepared by the manufacturer and submitted for approval, *see* Ch 1,3.3.

2.9 Anode weight

2.9.1 Anodes are to be weighed and individual anodes should be within ±5 per cent of the nominal weight for anodes less than 50 kg or ±3 per cent of the nominal weight for anodes 50 kg and over.

2.9.2 No negative tolerance is permitted on the total contract weight and the positive tolerance should be limited to two per cent of the nominal contract weight.

2.10 Bonding and internal defects

2.10.1 It will be necessary for the manufacturer to demonstrate that there is a satisfactory bond between anode material and the steel insert and that there are no significant internal defects. This may be carried out by sectioning of an anode selected at random from the batch or by other approved means.

2.10.2 Where sectioning is carried out, at least one anode or at least 0,5 per cent of each production run is to be sectioned transversely at 25 per cent, 33 per cent and 50 per cent of the nominal length of the anode or at other agreed locations for a particular anode design.

2.10.3 The cut surfaces are to be essentially free from slag or dross.

2.10.4 Small isolated gas holes and porosity may be accepted provided their surface area is not greater than two per cent of the section.

2.10.5 No section is to show more than 10 per cent lack of bond between the insert and the anode material.

2.11 Electrochemical testing

2.11.1 Electrochemical performance testing is to be carried out by the manufacturer in accordance with previously approved procedures designed to demonstrate batch consistency of the as-cast electrochemical properties.

2.12 Certification

2.12.1 The manufacturer is to provide copies of the Material Certificate or shipping statement for all acceptable anodes.

2.12.2 The certificate is to include at least the following information:

(a) Name of manufacturer.
(b) Description of anode, alloy designation or trade name.
(c) Cast identification number.
(d) Chemical composition.
(e) Details of heat treatment where applicable.
(f) Results of electrochemical test.
(g) Weight data.
(h) Purchaser's name and order number, and the name of the structure for which the material is intended.

2.12.3 The manufacturer is to confirm that the tests have been carried out with satisfactory results in accordance with the approved specification and the Rules.

2.13 Anode installation

2.13.1 The location and means of attachment of anodes are to be submitted for approval.

2.13.2 The anodes are to be attached to the structure in such a manner that they remain secure throughout the service life.

2.13.3 Where bracelet anodes are proposed the tightness of the anodes is not to rely on the anode material being in direct contact with the structure.

2.13.4 The location and attachment of anodes are to take account of the stresses in the members concerned. Anodes are not to be directly attached to the shell plating of main hull columns or primary bracings.

2.13.5 The anode supports may be welded directly to the structure in low stress regions provided they are not attached in way of butts, seams, nodes or any stress raisers. They are not to be attached to separate members which are capable of relative movement.

2.13.6 The attachment of all anodes to primary bracing members and nodes is to be submitted for approval. Anodes are not to be welded directly to the structure and the supports are to be welded to small doubler plates which are attached by continuous welds to the structure.

2.13.7 All welding is to be carried out by qualified welders using a qualified welding procedure in accordance with Chapters 12 and 13 of the Rules for Materials.

2.13.8 The welds are to be examined using magnetic particle inspection or other acceptable means of non-destructive testing in accordance with Chapter 13 of the Rules for Materials.

2.13.9 Anodes attached to studs 'fired' into the structure are not permitted.

2.13.10 The anodes are to be located on the structure to ensure rapid polarisation of highly stressed areas such as node welds and with due regard to a possible reduction in throwing power in re-entrant angles.

2.13.11 Anodes should not be located in positions where they may be damaged by craft coming alongside.

2.13.12 Magnesium anodes are not to be used in way of higher tensile steel or coatings which may be damaged by the high negative potentials unless suitable dielectric shields are fitted, *see* 2.2.1.

■ *Section 3* Impressed current anode systems

3.1 General

3.1.1 Impressed current anode materials may be of lead-silver alloy or platinum over such substrates as titanium, niobium, tantalum, or of mixed oxides-activated titanium. Anode materials and anode designs specified in BS EN 13173 or BS EN 12495 are also permitted.

3.1.2 The design and installation of electrical equipment and cables is to be in accordance with the requirements of Pt 6, Ch 2.

If hazardous areas are present on the facility, the impressed current cathodic protection system and equipment is to comply with the requirements of Pt 6, Ch 2 (in particular 5.1.3), Pt 7, Ch 2,8, 9, 10 and 11, IEC 60079 series and IEC 60092-502.

IEC 60092-502 Clause 5.7 'Cathodically protected metallic parts' states 'No impressed current cathodic protection shall be provided for metallic parts in hazardous areas, unless it is specially designed for this application and acceptable to the appropriate authority'.

The insulating elements required for the cathodic protection, for example, insulating elements in pipes and tracks, should if possible be located outside the hazardous area. *See* IEC 61892-7 Section 5.6.6.

3.1.3 All equipment is to be suitable for its intended location. Cables to anodes are not to be led through tanks intended for the storage of low flashpoint oils. Where cables are led through cofferdams of oil storage units they are to be enclosed in a substantial steel tube of about 10 mm thickness.

3.1.4 The arrangement for glands, where cables pass through shell boundaries, are to include a small cofferdam.

3.1.5 Cable and insulating material should be resistant to chloride, hydrocarbons and any other chemicals with which they may come into contact.

3.1.6 The electrical connection between the anode cable and the anode body is to be watertight and mechanically and electrically sound.

3.1.7 Where the power is derived from a rectified a.c. source, adequate protection is to be provided to trip the supply in the event of:

(a) A fault between the input or high voltage windings of the transformer (i.e., main voltage) and the d.c. output of the associated rectifier; or
(b) The ripple on the rectified d.c. exceeding 5 per cent.

The requirements for transformers and semi-conductor equipment are given in Pt 6, Ch 2,9.

3.1.8 Anodes may be installed by mounting in insulating holders attached directly to the submerged structural member provided the general requirements given in 2.13 regarding attachments to the structure are complied with.

3.1.9 Suitable dielectric shields are to be fitted in order to avoid high negative potentials.

3.1.10 A warning light or other warning indicator is to be arranged at the control position from which divers are controlled to indicate that the impressed current cathodic protection system has been switched off when divers are in the water.

3.2 Protection after launching and during outfitting

3.2.1 Where protection is primarily by an impressed current cathodic protection system, sufficient sacrificial anodes are to be fitted, capable of polarising the critical regions of the structure from the time of initial immersion until full commissioning of the impressed current system.

■ *Section 4* Fixed potential monitoring systems

4.1 General

4.1.1 A permanent monitoring system is to be installed on structures protected by an impressed current cathodic protection system, and, although not essential, such a monitoring system is recommended for use in conjunction with sacrificial anodes. Monitoring schemes shall comply with BS EN 13509 – *Cathodic protection measurement techniques*.

4.1.2 Zinc or Ag/AgCl reference electrodes should be used. Reference electrode materials and design specified in the above standard are also permitted.

4.1.3 The location and attachment of the reference electrodes are to take account of the stresses in the members concerned and they should not be attached in highly stressed areas or in way of butts, seams, nodes or any stress raisers.

4.1.4 The location of the reference electrodes should be such as to enable the performance of the cathodic protection system to be adequately monitored.

4.1.5 The reference electrodes may be connected to the top side display and control equipment by suitable cabling or by any other agreed means.

4.1.6 Provision is to be made for the regular recording at an agreed interval of the potential of the steelwork and log sheets are to be made available for inspection when required by LR Surveyors.

■ *Section 5* Cathodic protection in tanks

5.1 General

5.1.1 Impressed current cathodic protection systems are not to be fitted in any tank.

5.2 Sacrificial anodes

5.2.1 Particular attention is to be given to the locations of anodes in tanks that can contain explosive or other inflammable vapour, both in relation to the structural arrangements and openings of the tanks.

5.2.2 Aluminium and aluminium alloy anodes are permitted in tanks that may contain explosive or flammable vapour, or in ballast tanks adjacent to tanks that may contain explosive or flammable vapour, but only at locations where the potential energy of the anode does not exceed 275 J (28 kgf/m). The weight of the anode is to be taken as the weight at the time of installation, including any inserts and fitting devices. The height is to be taken as the distance from the bottom of the tank to the centre of the anode but exception to this may be given where the anodes are located on wide horizontal surfaces from which they cannot fall.

5.2.3 Aluminium anodes are not to be located under tank hatches or other openings unless protected by adjacent structure.

5.2.4 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast, in which case adequate venting must be provided.

5.2.5 Anodes fitted internally should preferably be attached to stiffeners, or aligned in way of stiffeners on plane bulkhead plating. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding at least 25 mm away from the edge of the web.

5.2.6 In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the mild steel face-plate but well clear of the free edges. Where higher tensile steel face-plates are fitted the anodes are to be attached to the webs.

5.2.7 Anodes are not to be attached directly to the shell plating of main hulls, columns or primary bracings.

5.2.8 For guidance on the design of sacrificial anode systems in tanks, *see* Ch 4,2.

■ *Section 6* Potential surveys

6.1 General

6.1.1 Potential surveys of the external submerged zones are to be carried out at agreed intervals, *see also* Pt 1, Ch 3.

6.1.2 Should the results of any potential survey measured with respect to a Ag/AgCl reference cell indicate values more positive than –0,8 volt for aerobic conditions or –0,9 volt for anaerobic conditions then remedial action is to be carried out at the earliest opportunity.

Section 7
Retrofits

7.1 General

7.1.1 Where it is proposed to fit additional anodes or replace existing ones, full details are to be submitted for consideration.

7.1.2 Where it is necessary to weld anodes to the structure, only approved welding procedures and consumables are to be used, in accordance with Chapters 12 and 13 of the Rules for Materials.

Section

Section 1
General requirements

1.1 General

1.1.1 The painting specification is to be submitted for approval, *see* Ch 1,3.5.1.

1.1.2 Paints, varnishes and similar preparations having nitrocellulose or any other highly flammable base are not to be used in accommodation or machinery spaces or in other areas with an equal or higher fire-risk.

1.1.3 Where a coating is to be applied in accommodation spaces and areas of similar fire-risk, the coating is to have low flame spread characteristics, *see* Ch 1,3.5.2(b).

1.1.4 Paints or other similar coatings containing aluminum should not be used in positions where flammable vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

1.1.5 Any sheathing or composition to protect decks is to be applied in such a manner that corrosion will not occur unseen beneath the covering.

1.1.6 Deck coatings or coverings used on decks forming the crown of spaces with a high fire-risk (such as helidecks, machinery and accommodation spaces) or which are within accommodation spaces, control rooms, emergency escape routes, etc., are to be of a type which will not readily ignite, *see* Ch 1,3.5.2(b).

1.1.7 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used.

1.1.8 Coatings are to be applied to blast cleaned surfaces prepared to at least an equivalent of ISO 8501-1 Sa $2^{1}/_{2}$. All resulting dust is to be removed from the surface prior to the application of any paint.

1.1.9 The selection, application and maintenance of coatings for dedicated sea-water ballast tanks (including pre-load tanks on self-elevating units), double-side skin spaces, etc., are also to comply with IMO Resolution MSC.215(82), *Performance Standards for Protective Coatings*. All dedicated sea-water ballast tanks and double-side skin spaces are to comply with all of the requirements of the Resolution.

1.1.10 Maintenance of the protective coating systems is to be included in the unit's overall maintenance scheme.

1.1.11 The paint (and/or primer) used on the inner hull of some LNG containment systems (particularly membrane type) requires the use of a suitable paint system to provide adhesion of the containment system (via a curing mastic) to the inner hull, in accordance with the designer's specification, as approved by LR.

Section 2
Prefabrication primers

2.1 General

2.1.1 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied.

2.1.2 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in 2.1.3 to 2.1.5. *See* Lloyd's Register's (LR's) *List of Paint Resins, Reinforcements and Associated Materials*.

2.1.3 Three butt weld assemblies are to be tested using plate material 20 to 25 mm thick. A vee preparation is to be used and prior to welding, the surfaces and edges are to be treated as follows:

(a) Assembly 1 – Coated in accordance with the manufacturer's instructions.
(b) Assembly 2 – Coated to a thickness approximately twice the manufacturer's instructions.
(c) Assembly 3 – Uncoated.

2.1.4 Tests as follows are to be taken from each test assembly:

(a) **Radiographs**. These are to have a sensitivity of better than two per cent of the plate thickness under examination, as shown by an image quality indicator.
(b) **Photo-macrographs**. These may be of actual size and are to be taken from near each end and from the centre of the weld.
(c) **Face and reverse bend test**. The test specimens are to be bent by pressure or hammer blows round a former of diameter equal to three times the plate thickness.
(d) **Impact tests**. Tests are to be carried out, at ambient temperature, on three Charpy V-notch test specimens prepared in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials*. The specimens are to be notched at the centreline of the weld, perpendicular to the plate surface.

2.1.5 The tests are to be carried out in the presence of an LR Surveyor or by an independent laboratory specialising in such work. A copy of the test report is to be submitted, together with radiographs and macrographs.

Section

Section 1 External steel protection

1.1 Current density

1.1.1 The current density required for the external protection of the submerged zone of units will depend on many factors such as water temperature, oxygen content, resistivity of the water, suspended solids, water currents and biological activity.

1.1.2 Design current density values are given in Table 4.1.1 for guidance purposes, but the values to be used should be based on the environmental conditions prevailing at the site. It should be noted that these values may be appreciably different from values actually measured on steelwork in the vicinity of the site.

Table 4.1.1 Current density values for design purposes

Location		Current density mA/m^2
Cook inlet		400
North Sea (Northern)	Above 62°N 55°N to 62°N	130 120
US (West Coast)		100
North Sea (Southern) Africa Brazil China India Mediterranean	Below 55°N	90 90 90 90 90 90
Australia (Western) Gulf Gulf of Mexico		80 80 80
Mud – Most locations		20
Drainage per well		5A

NOTES
1. The current density values are intended for guidance purposes in the design of sacrificial anode systems using the methods as outlined in this Chapter. However, other values may be accepted provided that there is adequate justification.
2. For impressed current cathodic protection systems, current densities higher than the values given in the Table may be necessary but this will depend on the type and location of the anodes.

1.1.3 In order to minimise pitting, the cathodic protection system must be capable of rapidly polarising the steelwork and it is recommended that the initial current density should be appreciably higher than the values given in Table 4.1.1.

1.1.4 Although a lower current density may be capable of maintaining polarisation, the cathodic protection system must be capable of re-polarising the steelwork rapidly after storms, even when the anodes are well wasted.

1.1.5 Where suitable high resistance coatings are used, consideration will be given to use of current densities lower than those given in Table 4.1.1.

1.1.6 Coatings will deteriorate with time and there is likely to be mechanical damage. In order to take this into account at the design stage, appropriate coating breakdown factors should be applied and these are to be based on the percentages given in 1.1.7.

1.1.7 For an epoxy or coal tar epoxy coating applied to give a dry film thickness of 250 to 500 microns, an initial coating breakdown of one to two per cent for the submerged zone and an annual degradation rate of one to three per cent per year should be used.

1.2 Sacrificial anode systems

1.2.1 The following indicates an acceptable method for determining the number and weight of anodes to achieve the required level of polarisation on most structures. Other methods may be accepted provided they give reasonable equivalence.

1.2.2 The type of anode selected must be of sufficient mass with appropriate dimensions to ensure an adequate current output throughout its design life.

1.2.3 The current output of the anode should be calculated using the following formula:

$$I_a = \frac{\Delta V}{R_a}$$

where

I_a = current output of anode, in amps
ΔV = driving potential, i.e., the difference between the potential of the mode and the protected steel potential, in volts
R_a = anodic resistance, in ohms.

1.2.4 The potential of the polarised steel should be taken as –0,8 volt (Ag/AgCl/sea-water reference electrode), although a more negative value may be used for those locations where sulphate-reducing bacteria may be active, *see* Ch 2,1.3.

1.2.5 The resistance of an anode, R, with small cross-section in relation to its length and with a stand-off distance from the bottom of the anode surface to the structure of not less than 300 mm, is given by:

(a) $$R = \frac{\rho}{2\pi l_a}\left(ln\frac{4l_a}{r} - 1\right)$$

where

ρ = resistivity of sea-water, in ohm.cm
l_a = length of anode, in cm
r = equivalent radius of anode, in cm
ln = $\log_e$

$$r = \sqrt{\frac{a}{\pi}}$$

a = cross-sectional area of the anode, in cm^2

(b) When bracelet anodes are used, the resistance may be determined using:

$$R = \frac{0{,}315\rho}{\sqrt{A_e}}$$

where

A_e = the exposed surface area of the anode, in cm^2.

1.2.6 In order to achieve a suitable anode distribution on tubular structures, each appropriate section of steelwork should be considered separately.

1.2.7 The current required for each section may be determined from the following:

$$I_r = \frac{A\,I}{1000}$$

where

I_r = current, in amps
A = area of steelwork, in m^2
I = current density, in mA/m^2.

1.2.8 The number of anodes, N, required should satisfy both of the following:

$$N = \frac{I_r}{I_a}$$

$$N = \frac{W_r}{W_a}$$

where

I_r = current, in amps
I_a = current output of anode, in amps
W_r = net weight of anode material, in kg
W_a = net weight of individual anode, in kg

$$W_r = \frac{I_r\,Y\,8760}{C\,U}$$

Y = life of structure or appropriate dry-docking interval in years, *see* Ch 2,1.1.1
C = practical electrochemical capacity of the alloy, in Ah/kg
U = utilisation factor, i.e., proportion of net weight consumed at end of anode life. For fully supported tubular inserts
U = 0,9
U = 0,8 for bracelet (half shell)
U = 0,75 for bracelet (segmental type).

In order to optimise the performance and efficiency of the anodes the values for both equations should be similar.

1.2.9 It is to be shown by appropriate calculations that the system is capable of polarising the structure initially and also when the anodes are consumed to their design utilisation factor.

1.2.10 It should be assumed that, at the end of its life, the anode length has been reduced by 10 per cent and that the remaining material is evenly distributed over the steel insert.

1.3 Location of anodes

1.3.1 Having determined the number and size of the anodes to comply with the recommended nominal current density and the required life, the anodes should be distributed over the steel surfaces according to the required level of protection on the steelwork but with some emphasis on the area adjacent to joints, etc. The anodes associated with the structure likely to become buried, such as footings, etc., should be positioned on the steelwork immediately above the mudline.

■ *Section 2* **Protection of tanks**

2.1 Anode resistance

2.1.1 Where large stand-off anodes are used for the protection of tanks, the resistance should be determined using the formula as given in 1.2.5(a).

2.1.2 Where flat plate anodes are used, their resistance is to be determined from the following formula:

$$R = \frac{\rho}{4l_m}$$

however, if the flat plate anodes are close to the structure or painted on the lower face then the resistance is to be determined using:

$$R = \frac{\rho}{2l_m}$$

where ρ is as defined in 1.2.5
l_m = mean length of anode sides, in cm.

2.2 Current density

2.2.1 The design current density to be used for permanent water ballast tanks should be based on a minimum value of 110 mA/m^2 but this may have to be increased to at least 130 mA/m^2 if hot oil is stored on the opposite side of the bulkhead. For a coating allowance, *see* 1.1.6.

2.2.2 Uncoated tanks used for the storage of crude oil at ambient temperature alternating with water ballast are to have a minimum current density of 90 mA/m^2; however, this should be increased for higher temperatures.

2.2.3 Unless otherwise agreed the resistivity of the water in ballast tanks should be assumed to be 25 ohm.cm.

2.3 Anode distribution

2.3.1 Once the number and size of anodes have been determined, they are to be distributed as follows:

(a) **Ballast-only tanks**: evenly over all the steelwork.

(b) **Crude oil/ballast tanks**: evenly but with some emphasis on horizontal surfaces in proportion to the area of these surfaces.

2.4 Reference electrodes

2.4.1 Variations between electrodes of ±30 mV have been reported for zinc/sea-water reference electrodes and ±5 mV for silver/silver chloride/sea-water electrodes but unless a high degree of stability is required, either electrode may be used for comparison purposes. The zinc/sea-water electrode may be taken as approximately 1,03 V more positive than the silver/silver chloride/sea-water electrode.

■ *Section 3*
Surface preparation, application and maintenance of coatings

3.1 Application

3.1.1 These notes have been prepared to give general guidance on those aspects of surface preparation and application and the subsequent maintenance of coatings that should be taken into account by those agreeing the coating specification.

3.1.2 These notes are not intended to be used for contractual purposes or as representing the minimum requirements as these are a matter for the interested parties to agree.

3.1.3 The guidelines do not intend to replace the technical aspects of any specific coating system, to be covered by the product and job specifications, which are at the discretion and under the responsibility of Owners, manufacturers and construction yards.

3.1.4 Owners should select and maintain a corrosion protection system to ensure an adequate level of protection.

3.1.5 Coating manufacturers should give evidence of the quality of the product and its ability to satisfy the Owner's requirements.

3.1.6 Coating manufacturers should have products with documented service performance records. Coatings recognised by Lloyd's Register (LR) are considered as satisfying this requirement, *see* list of LR approved PSPC compliant coatings on CD Live. Where it is proposed to use coatings without satisfactory performance records, coating selection should be supported by appropriate laboratory test data carried out in accordance with recognised Standards (e.g., ISO 20340) in order to verify their suitability for the intended service condition.

3.1.7 The construction yard and/or its subcontractors should provide clear evidence of their experience in coating application. The coating standard, job specification, inspection, maintenance and repair criteria should be agreed by the construction yard and/or its subcontractors, Owner and manufacturer.

3.2 General requirements

3.2.1 At present, hard coatings are the most commonly used for new construction.

3.2.2 As their effectiveness and life are influenced by several factors it is essential that the manufacturer's technical product data sheet and job specifications are followed.

3.2.3 Multi coat applications with coating layers of contrasting colours are recommended. The last coating layer in ballast tanks should be of a light colour in order to facilitate in-service inspections.

3.2.4 Measures should be adopted at the design stage to reduce scallops, use rolled profiles (provided this does not adversely affect fatigue performance) or three-pass grinding where possible and ensure that the structural configuration permits easy access for personnel and equipment and facilitates cleaning, draining and drying of tanks.

3.2.5 Where a coating is supplemented by cathodic protection, the coating must be compatible with the cathodic protection system.

3.3 Coating selection

3.3.1 In the selection of a coating for use in ballast tanks, the following should be taken into account:

- Service conditions and planned maintenance.
- Frequency of ballasting/deballasting operations.
- Location of tank relative to heated surfaces.
- Required surface condition.
- Required surface cleanliness and dryness.
- Whether cathodic protection is to be fitted.
- Requirements of IMO Resolution MSC.215(82) *Performance Standards for Protective Coatings*.

3.3.2 Coatings intended for use underneath solar heated decks or on bulkheads forming boundaries of heated cargo or fuel oil spaces should be able to withstand constant or repeated heating without becoming brittle or subject to a loss of adhesion. Due regard should be given to the possible poor edge-covering properties of hard coatings with a high solid content.

3.4 Initial preparation

3.4.1 Tubular scaffolding should not mask surfaces to be coated. Where contact is necessary, spade ends should be used.

3.4.2 Staging should afford easy and safe access to all surfaces to be coated.

3.4.3 Tubular scaffolding should be plugged or capped prior to blast cleaning to prevent the ingress of grit and dirt.

3.4.4 Staging should be designed to allow thorough cleaning.

3.4.5 Staging layout should be such that ventilation is not rendered ineffective.

3.4.6 Care should be taken when removing scaffolding in order to keep damages to a minimum. Any damages should be repaired in accordance with the paint manufacturer's recommendations.

3.4.7 External surfaces of pipelines which will be covered by pipe clips should be blasted and coated prior to fitting.

3.4.8 Pipeline exteriors should be blasted and coated at the same time as the lowermost parts of the tank. Any over-blast or over-spray affecting surrounding areas should be repaired.

3.4.9 Lighting during blasting and painting must be electrically safe and provide suitable illumination for all work.

3.4.10 Powerful spotlighting must be provided for inspection work.

3.4.11 Adequate ventilation during application and drying of all paints is essential.

3.4.12 Flexible ventilation trunking should be used to allow the point of extraction to be reasonably close to the applicator.

3.4.13 The ventilation system and trunking should be so arranged that 'dead spaces' do not exist. Ventilation must be maintained during application and continued whilst solvent is released from the paint film during drying.

3.4.14 The ventilation system must prevent the vapour concentration exceeding 10 per cent of the lower explosive limit (or less than this if required by Regulations).

3.4.15 For coatings containing organic solvents, during the drying period an adequate number of air changes must be effected, depending on the type of coating being used. This ventilation should be maintained for at least 48 hours after the application of the system.

3.5 Surface preparation

3.5.1 Good surface preparation is one of the most important factors governing the performance of a coating. If contaminants such as oil, grease, dirt and chemicals are not removed from the surface they will prevent the adhesion of the coatings. Soluble salts on the surface may lead to osmotic blistering in the coating. Rust left on the surface will loosen, resulting in a loss of adhesion and if mill scale is not completely removed it will cause accelerated corrosion.

3.5.2 Good surface preparation roughens the surface and enables a good mechanical bond to be achieved.

3.5.3 The surface preparation for coatings should be in accordance with the coating manufacturer's specification. All oil and grease is to be removed from the surface with suitable solvents prior to blast cleaning.

3.5.4 All welded areas and attachments are to be given special attention for the removal of welding flux and weld spatter. Sharp edges should be smoothed and any surface irregularities, including rough weld caps and slag together with rough edges, fins and burrs, should be mechanically treated using power wire brushing, grinding or chipping as appropriate.

3.5.5 Only dry abrasive blast cleaning techniques are to be employed and the conditions under which blast cleaning is carried out should preclude condensation. In this respect blasting should not normally be carried out under any of the following conditions:

(a) The surface temperature of the steel is less than 3°C above the dew point.
(b) The relative humidity is above 85 per cent.
(c) When there is any possibility that the surface of the steel is wetted before the first coat is applied.

3.5.6 The compressed air supply used for blasting is to be free of water and oil and adequate separators and traps are to be provided. Prior to using compressed air, the quality of the air downstream of the separator should be tested by blowing the air on to a clean white blotter or cloth for two minutes to check for any contamination, oil or moisture. This test should be performed at the beginning and end of each shift and at not less than four-hour intervals. The test also should be made after any interruption of the air compressor operation. The air should be used only if the test indicates no visible contamination, oil or moisture. If contaminants are evident, the equipment deficiencies should be corrected and the air stream should be retested.

3.5.7 Accumulations of oil and moisture are to be removed by regular purging of the system. Air compressors should not be allowed to work at temperatures in excess of 115°C.

3.5.8 The abrasive used for blasting should be dry and free from dirt, oil or grease and suitable for producing the standard of cleanliness and profile specified. Additionally, any organic or water soluble matter should be a maximum of 0,05 per cent by weight.

3.5.9 Iron or steel abrasives are not normally recommended for *in-situ* open blasting. If used, careful and thorough cleaning must be carried out to remove all traces of abrasive from the surface.

3.5.10 Although not recommended, recycled grit may be used providing it is correctly graded, dry and free from dirt, oil, grease, organic or water soluble matter. Recirculated grit should be checked for the presence of oil by immersing a sample in water and examining for oil flotation. Tests should be made at the start of blasting, and every four hours until the end of blasting. If compressor operations are interrupted for longer than five minutes, the air supply should be retested prior to use. If oil is evident, the contaminated abrasive should be cleaned or replaced. All surfaces blasted since the last successful test should be completely reblasted.

3.5.11 The amplitude of blast profile from trough to adjacent peak depends upon the type of coating to be applied. The amplitude should be not more than 50 μm for coatings of the zinc silicate type and not more than 75 μm of the high build coatings. A procedure to measure the surface profile of abrasive blast cleaned steel on site is given in NACE RP 0287.87. The technique utilises a tape that replicates the surface profile and the thickness of the tape is then measured using a micrometer.

3.5.12 Generally, where the final dry film coating is 125 μm or less, it should be in accordance with ISO 8501-1 Sa3 or an equivalent standard, i.e., the surface is to be cleaned to white metal such that a uniformly metallic, slightly roughened surface is produced completely free from foreign matter. Shadowed areas may only be accepted if they are due to differences in the structure of the steel or to a blast cleaning pattern. It should be noted that the possibility of achieving a uniform standard of Sa3 throughout the tanks is remote and a more realistic achievement would be somewhere between Sa2$^1/_2$ and Sa3.

3.5.13 The standard of surface preparation for the majority of the coatings is to be at least in accordance with ISO 8501-1 Sa2$^1/_2$ or an equivalent standard, i.e., the blast cleaned surface is to consist of at least 95 per cent cleaned bare steel and not more than 10 per cent of any single 25 mm square of the surface area is to be discoloured by areas of rust stain or mill scale residues.

3.5.14 In cases where the substrate is corroded or pitted it may be necessary to fresh water wash the areas after abrasive blasting, then reblast, in order to ensure complete removal of soluble corrosion products.

3.5.15 No acid washes or cleaning solutions are to be used on metal surfaces after they have been blasted. This includes inhibitive washes intended to prevent rusting.

3.5.16 Any substandard areas should be identified and must be brought up to the specified standard. Grease free chalk should be used to identify substandard areas and it should be removed after the substandard areas have been rectified.

3.5.17 After blast cleaning, all surfaces are to be freed of abrasive and dust by:
(a) Blowing with dry compressed air; or
(a) Vacuum cleaning.
To confirm that the blasted surfaces are sufficiently dust-free to allow successful coating, they are to be tested in accordance with ISO 8502-3 or an equivalent standard, to an extent and with acceptance criteria defined by the coating manufacturer.

3.5.18 Where surfaces have been coated with a prefabrication primer they are to be similarly cleaned before application of the coatings. If there is extensive breakdown of the primer, the surface affected is to be reblasted.

3.5.19 Since fresh blast cleaned surfaces are subject to immediate corrosion, particularly in areas of high humidity or in a marine atmosphere, it is essential that all cleaned surfaces are coated within four hours of cleaning. In any case, the surfaces are to be coated prior to the end of the working day and before any visible rusting occurs unless humidity can be maintained overnight at a low level.

3.5.20 Checks on the steel surface cleanliness and roughness profile should be carried out at the end of the surface preparation and before the application of the primer and in accordance with the manufacturer's specifications.

3.5.21 Where abrasive blast cleaning is demonstrated to be impracticable at specific locations, alternative mechanical surface cleaning techniques may be applied. In such circumstances, the surface cleanliness should be in accordance with ISO 8501-1 St3 or an equivalent standard and particular attention must be given to ensuring that the surface profile and soluble salt concentrations are in accordance with the coating manufacturer's specification.

3.6 Coating requirements

3.6.1 The composition of any primer used to coat steel after surface preparation and prior to fabrication must be such that it will have no significant deleterious effect on subsequent welding work.

3.6.2 The coatings are to be compatible with any prefabrication primer used and suitable for the intended application.

3.6.3 Materials are to be delivered in original containers with labels intact and the seals unbroken. Containers are to be kept in a safe, clean, well ventilated storage space.

3.6.4 Before use, coatings are to remain unopened in the original containers. Covers are to be kept on opened coating containers when not in use. Coatings are to be used in strict date order and not stored longer than six months unless permitted by the paint manufacturer.

3.6.5 The coating manufacturer's instructions are to be followed for storage, mixing, thinning and application of coatings along with the recommended time limit between coats and health and safety precautions. Only the thinners recommended by the manufacturer are to be used to thin coatings.

3.6.6 Coatings are to be mixed immediately prior to application. All coating materials are to be thoroughly mixed to give a homogeneous liquid without pigment settling out during application. Mechanical mixers are to be used for all coating mixing operations. The entire contents of the coating container are to be used in mixing to ensure the correct proportion of the base coat and pigment.

3.6.7 Coating material which has livered, discoloured, gelled, or otherwise deteriorated during storage is not to be used. Thixotropic materials which may be stirred to obtain normal consistency may be acceptable.

3.6.8 For coating materials requiring the addition of a catalyst, the pot life under application conditions is to be clearly stated on the label, and this pot life is not to be exceeded. When the pot life limit is reached, the spray pot is to be emptied, material discarded, and new material mixed.

3.6.9 Specification and data sheets on the coating materials are to be available at all times.

3.7 Coating application

3.7.1 The application of a coating should be a well planned activity, integrated in the yard's construction plans and carried out under controlled conditions to avoid conflicts with other yard operations.

3.7.2 Coatings should be applied in controlled humidity and surface temperature conditions to surfaces which have been blast cleaned to the coating manufacturer's recommended standard and immediately coated with a compatible prefabrication primer or applied after blast cleaning if this is permitted by the specification.

3.7.3 Areas where the prefabrication primer is damaged in any way may be touched up in accordance with the manufacturer's specifications.

3.7.4 Each coating layer should have the maximum/ minimum thicknesses in accordance with the coating specification. Generally, an 80/20 practice may be adopted which means that 80 per cent of all thickness measurements should be greater than or equal to the nominal dry film thickness (DFT), and none of the remaining 20 per cent is below 80 per cent of the DFT. In the case of tanks (and especially ballast tanks), consideration should be given to adopting a 90/10 practice which means that 90 per cent of all thickness measurements should be greater than or equal to the nominal DFT, and none of the remaining 10 per cent is below 90 per cent of the DFT.

3.7.5 All paints should be applied by airless spray except for stripe coats where brushes or, if recommended by the coating manufacturer as a preferred option, rollers may be used.

3.7.6 Conventional spray may be used for the spraying of zinc silicate tank coatings.

3.7.7 Efficient mechanical stirrers for the correct mixing of paint should be used.

3.7.8 The spray equipment should comply with the paint manufacturer's recommendations. Adequate moisture traps should be fitted where appropriate so that water or oil can be continuously bled off from the air supply.

3.7.9 Lines and pots are to be thoroughly cleaned before using different materials.

3.7.10 With the possible exception of wet blast primers and moisture cured products, coatings should not be applied to damp surfaces and the specification should stipulate that coatings are not to be applied to surfaces where the relative humidity of the atmosphere is such that:

(a) Condensation is present on the surface; or
(b) It will affect the application of drying of the coating.

3.7.11 No coating is to be applied if the temperature is below that specified by the coating manufacturer and, in general, the metal surface temperature should be at least 3°C above the dew point before painting is commenced. The temperature, dew point, and relative humidity should be determined with a sling psychrometer. Suitable procedures are given in ASTM E337. Readings are required at the start of work and every four hours.

3.8 Coating thickness

3.8.1 Generally, high duty coatings should be applied in at least two coats; however, 'wet-on-wet' application may be considered as a two coat system provided:

(a) There is a time interval between the coats; and
(b) There is adequate attention to difficult areas such as welds, edges and any other changes in section and that the recommended coating thickness is achieved over all the structure.

3.8.2 Where coatings other than the zinc silicate type have been accepted as a single coat application, all welds, edges and any other changes in section may require a stripe coat to be applied.

3.8.3 Successive coats should preferably be of different colours or with a significant shade variation to give contrast and ensure complete coverage of the surface, *see also* 3.2.3.

3.8.4 All surfaces are to receive the full thickness specified as a minimum. Areas with inadequate coating thickness should receive additional compatible coats until the specified coating thickness is attained. Coatings are to be brushed on to all areas which cannot be properly coated by spray.

3.8.5 Care should be taken to avoid an excessive coating thickness as this could lead to serious consequences, such as solvent and thinner retention, film cracks, gas pockets, etc. Wet coating thickness should be checked during application.

3.8.6 Each coating layer should be adequately cured before application of the next coat, in accordance with coating manufacturer's recommendations. Intermediate coats must not be contaminated with dirt, grease, dust, salt, over-spray, etc. Job specifications should include the dry-to-re-coat times given by the manufacturer.

3.8.7 Thinners should be limited to those types and quantities recommended by the manufacturer.

3.9 Inspection and repair

3.9.1 Wet film thickness checks should be made as the work progresses using appropriate thickness gauges.

3.9.2 Dry film thickness determinations should be carried out on all significant areas using suitable gauges. (The simple pull-off type gauges are not considered sufficiently accurate for this work.)

3.9.3 The full number of coats specified should be applied and the specified film thickness achieved.

3.9.4 All coatings should be free of pin holes, voids, bubbles and other 'holidays'. Holiday testing should be carried out using a suitable 'holiday detector' set at an appropriate voltage for the coating system.

3.9.5 Any defective areas are to be marked up and appropriate repairs effected. All such repairs are to be rechecked for any uncoated areas.

3.9.6 A daily log of the following is to be prepared:

(a) Air and steel temperatures.
(b) Relative humidity.
(c) Paint thicknesses measured.
(d) Extent of coating.
(e) Any other relevant information.

3.9.7 Damage to coatings is to be repaired by cleaning back to a sound base, recoating the affected areas as required in the specification and feathering to tie with adjoining areas. Prior to the application of any coating, all damage to previous coats is to have been repaired.

3.9.8 The area to be cleaned is to be carried over onto the firm surrounding coating for not less than 25 mm all round the edges. These are to be feathered by a suitable method to ensure continuity of the subsequent repair coating.

3.9.9 Areas with inadequate coating thickness are to be thoroughly cleaned and, if necessary, abraded and, where applicable, additional coats applied until the specification is complied with. These additional coats are to blend in with the final coating at adjoining areas.

3.9.10 Where welding has to take place on coated areas, unless they are approved prefabrication primers the coatings are to be removed locally and the surface after welding is to be prepared and recoated in accordance with the recommended procedures.

3.9.11 When dry film thicknesses are less than those specified, additional coats are to be applied as necessary to achieve specified thickness. For inorganic zinc silicate, areas of low film thickness should not be repaired by additional coats. In this case the coating is to be removed and the area re-coated to the specified thickness.

3.10 Safety aspects

3.10.1 It should be noted that paints, coatings and thinners are potentially hazardous from health and safety points of view if not strictly controlled in accordance with good practice. Detailed advice on the safe working practices to be followed should be obtained from the relevant governmental safety agencies.

3.11 Maintenance

3.11.1 Maintenance of the corrosion protection system should be included in the overall maintenance schemes.

3.11.2 The most efficient way to preserve the corrosion protection system is to repair any defects found during the in-service inspections (e.g., spot rusting, local breakdown at edges of stiffeners, etc.).

3.11.3 During maintenance hard coatings should be restored using the type originally applied or by a compatible hard coating recognised by LR. The compatibility of coatings should normally be agreed by the paint manufacturer, and the coatings should be applied in accordance with the manufacturer's requirements.

3.11.4 The restoration of the damaged hard coatings by compatible coatings not recognised by LR will be accepted, provided such coatings are applied and maintained in accordance with the manufacturer's specification. Details of such coatings are to be reported for information and record purposes.

3.11.5 If the required conditions for the application of the original coating are not achievable, a coating more tolerant of a lower quality of surface treatment, humidity and temperature conditions may be considered, provided that it is applied and maintained in accordance with the manufacturer's specifications.

3.11.6 Currently there are numerous non-oxidising soft coatings which are being marketed for the purpose of repairing hard coatings. Proposals to use this type of coating, including the manufacturer's confirmation of their compatibility with the existing coatings, are to be referred for consideration.

3.11.7 It should be noted that soft coatings are, in general, not suitable for use in association with cathodic protection.

Rules and Regulations for the Classification of Offshore Units

Part 9
Concrete Unit Structures

July 2014

Lloyd's Register

Chapter Contents Part 9

Contents

Part 9

Contents

Section 1 General

1.1 Application

1.1.1 The Chapters in this Part outline the structural design requirements of ship and barge type units, built in reinforced and/or pre-stressed concrete. The design for other types of floating concrete units will be specially considered, although the general principles given in this Part are applicable. The general requirements for structural unit types in Pt 4, Ch 4 and Ch 5 are to be complied with as applicable.

1.1.2 This Part only considers the design requirements for the concrete structure of the unit. The requirements of this Part are considered to be supplementary to the requirements in the relevant Parts of the Rules.

1.1.3 These Rules are intended primarily for units engaged in production and/or crude oil storage as defined in Pt 3, Ch 3, to which reference should be made.

1.1.4 Special consideration will be given to units required for the storage of liquefied gas or liquid chemicals in bulk. The following technical aspects are to be considered in full for the storage of liquefied gas:

(a) selection of gas containment system;
(b) interaction between concrete structure and containment system;
(c) the effects of temperature on the concrete, *see* Ch 4,2.6;
(d) fixing/embedding the containment system supporting structure in concrete;
(e) arranging a moisture barrier where considered necessary.

1.2 Recognised Codes and Standards

1.2.1 These Rules give requirements for detailed design. Recognised Codes and Standards which give an equivalent level of safety will be considered but must be agreed by Lloyd's Register (LR) in each case.

1.3 Class notations

1.3.1 The Regulations for classification and the assignment of class notations are given in Pt 1, Ch 2, to which reference should be made.

1.3.2 In addition to the normal class notations which may be assigned to an installation, for concrete units a suitable descriptive note will be included in the *Offshore Register,* e.g., **concrete hull**.

1.4 Plans and data submission

1.4.1 Plans, calculations, data and specifications are to be submitted in accordance with Pt 4, Ch 1,4 as per steel structures, as applicable.

1.4.2 For units with process plant or drilling plant, the additional plans and information required by Pt 3, Chapters 7 and 8, as applicable, are also to be submitted.

1.4.3 In addition to the above requirements, plans are to contain reinforcement and pre-stressing details for the whole concrete structure.

1.4.4 Calculations are also to be submitted for the serviceability and progressive collapse limit states in addition to the ultimate strength and fatigue calculations required in Pt 4, Ch 1, 4.3.1.

Section 2 Design principles

2.1 Semi-probabilistic approach

2.1.1 These Rules for concrete structures assume the use of a semi-probabilistic analysis with characteristic values of loads and strengths of materials in association with partial safety factors. Departure from the partial safety factors or other design criteria given in these Rules is to be agreed with LR.

2.1.2 Other design approaches can be accepted, subject to approval.

2.2 Limit state design

2.2.1 The aim of this design method is the achievement of an acceptable probability that the structure or part of a structure being designed will not reach a particular state, called a limit state, in which it infringes one of the criteria governing its strength, durability or use.

2.2.2 The limit state categories are outlined in Section 3. The required loads and load combinations are given in Chapter 2 and structural design in Chapter 3.

Section 3 Limit states of design

3.1 Ultimate Limit State (ULS)

3.1.1 The strength of the structure is to be sufficient to ensure that under the worst combination of wave loads, still water loads and mooring loads, the structure will not collapse, buckle or implode, *see also* Ch 3,4.2.

3.1.2 Individual sections are to be checked for rupture. Consideration is also to be given to the mode of failure. In general, the initiation of failure of primary members by compression or shear is to be avoided.

3.2 Serviceability Limit State (SLS)

3.2.1 The serviceability limit is selected to ensure that the structure will meet the requirements for deflection, durability, liquid tightness and cracking under service conditions, *see also* Ch 3,4.3.

3.2.2 The deflection of the structure or any part of the structure is to be limited such that it does not adversely affect the efficiency of the structure. Deflections are to be compatible with the degree of movement acceptable for the operation of services, etc. Any particular requirements should be specified by the Owner.

3.2.3 The durability of the structure is dependent upon the mix design, the concrete cover, control of cracking by the reinforcement, and exposure conditions. Requirements for concrete mix and cover are given in Chapter 4.

3.3 Fatigue Limit State (FLS)

3.3.1 The designer is to demonstrate that the structure is not susceptible to fatigue failure. Agreement is to be reached with LR on the areas of the structure which are potentially vulnerable to fatigue. In particular, the oil storage tank area and the turret area are to be specially considered.

3.3.2 A fatigue analysis of critical areas is to be carried out based on the principle of cumulative damage, or fracture mechanics, *see also* Ch 3,4.4.

3.3.3 The dynamic behaviour of the unit is to be investigated to determine whether the increase in load effects due to dynamic amplification is significant.

3.4 Accidental (ALS) and Progressive Collapse Limit State (PCLS)

3.4.1 The layout of the structure and the interaction between the structural members are to be such as to ensure a robust and stable design.

3.4.2 Consideration is to be given to redundancy and the possibility of progressive collapse. The designer must ensure that there is sufficient strength or redundancy to prevent this occurring. This requirement relates particularly to accidental or exceptional loads. Consideration is to be given to both the intact and post damaged condition.

3.4.3 Environmental return periods for use in post damaged conditions are given in Table 2.2.1.

Section

Section 1
General

1.1 Application

1.1.1 For definitions of applied structural loads, methods of load calculation and load combinations, *see* Pt 4, Ch 3, 4. The additional requirements for structural unit types defined in Pt 4, Ch 4 and Ch 5, as applicable, and the requirements of this Chapter are to be complied with.

Section 2
Definitions

2.1 Permanent loads

2.1.1 The following can be considered permanent loads:

- Weight of structure.
- Weight of permanent ballast and equipment.
- Buoyancy to support permanent loads.

2.1.2 Any long-term reduction in buoyancy due to water absorption into the concrete should be considered. Similarly, any long-term increase in weight due to absorption of internal fluids such as oil or ballast water should also be considered.

2.2 Live loads

2.2.1 Live loads are related to the operation of the unit and can vary in magnitude. The following can be considered as examples:

- Pressure of liquid cargo and variable ballast.
- Mooring loads for the still water condition.
- Weight of stored materials and equipment.
- Loads associated with process operation.
- Crane and helicopter operations.
- Buoyancy to support live loads.

2.3 Environmental loads

2.3.1 The assessment of environmental loads may be based on the results of model tests or by suitable direct calculation of the actual loads on the hull at the specific location, taking into account the following service related factors:

(a) Site-specific environmental conditions.
(b) Mooring loads due to the environment.
(c) Weathervaning with wave loadings predominantly from one direction.
(d) Long-term service effects at a fixed location.
(e) Range of tank loading conditions.

2.3.2 The characteristic value of the environmental load for a given limit state is to be the most unfavourable value calculated for the specified environmental return period, *see* Table 2.2.1.

2.3.3 In assessing the values for wave, wind and current in a given environmental return period event, allowance can be made for joint probability, provided this can be documented.

2.3.4 All external water pressures due to waves above the unit's maximum operating draught are to be considered as environmental loads.

2.3.5 Pressure heads due to wave impact loading at the fore end of concrete structures will be specially considered. In harsh environments a site-specific assessment is to be carried out to determine equivalent design pressure heads on the shell envelope. Where model tests are carried out, arrangements should be made to measure bow impact wave pressures, *see also* Pt 4, Ch 3,4.1.5.

2.3.6 Loads from green seas on the deck and fore structure are to be considered as an environmental load. It is not necessary to include these loads in the overall bending moment for the hull strength, but they should be considered as a local ULS load on deck panels with the appropriate load factors. Minimum design deck pressures for this condition can be obtained from Pt 4, Ch 7, except where model tests indicate higher loadings, *see also* Pt 4, Ch 3,4.1.5 and Pt 10, Ch 1,11.

2.3.7 All hydrostatic pressures due to waves and internal sloshing forces are to be considered as environmental loads.

2.4 Deformation loads

2.4.1 Deformation loads on the structure shall be considered. These can result from the following sources amongst others:

- Temperature.
- Creep.
- Shrinkage.
- Pre-stressing.

2.4.2 For concrete structures the effects of cargo temperatures relative to seasonal ambient temperatures are to be considered for both sea and air temperatures, as appropriate for the section being assessed.

Table 2.2.1 Basis for selection of return periods for environmental loads

Limit State / Load	ULS	SLS	FLS	PLS		
				Intact		Damage
				Accidental	Abnormal, *see* Note 5	*see* Note 4
Environmental (E)	100	S *see* Note 1	Exp *see* Note 2	10 000 *see* Note 3	10 000	10
Accidental (A)	—	—	—	10 000 *see* Note 3	—	—

NOTES
1. For SLS, two conditions are required to be assessed, *see* Ch 3,4.3.
   (a) Normal serviceability – this is selected such that the environmental loads will not be exceeded more than 100 times in the design life of the structure. In the absence of a more detailed assessment, for a typical 25-year design life, actions may be assumed to be 60% of the characteristic load for a 100-year return period event.
   (b) Modified serviceability – 100-year return period event.
2. Exp = Expected Load History.
3. The combined return period of occurrence for the environmental and accidental loads is not to be greater than 10 000 years. In practice, dropped objects and collision loads against the hull will normally cause only local damage and hence need not be combined with environmental loads.
4. Where the PLS intact analysis shows little or no damage, the PLS damage condition need not be investigated.
5. The abnormal event is not a requirement for class but may be required to be assessed by some national or coastal state authorities.

2.5 Accidental and abnormal loads

2.5.1 Accidental loads are defined in Pt 4, Ch 3,4.2.4 and 4.16. In addition, the failure of an oil cooling system, if fitted, is to be considered.

2.6 Characteristic value of loads

2.6.1 For the loads defined in this Section, the characteristic value of the individual loads are as follows:

Permanent	–	calculated value.
Live	–	calculated or specified value.
Environmental	–	most unfavourable value for specified return period, *see* Table 2.3.1.
Deformation and Accidental	–	specified value unless controlled by environmental considerations.

■ *Section 3* Load combinations

3.1 Load factors and load combinations

3.1.1 The general principles for load combinations for marine service are given in Pt 4, Ch 3,4.3.1. Details of all load combinations for use with concrete structures, with the appropriate load factors, are given in Table 2.3.1 for the various limit states.

3.1.2 The design load is usually taken as the characteristic load multiplied by the appropriate load factor. However, for floating structures it is necessary for the load factors to be such that each load combination considered is in equilibrium with regard to applied loads and buoyancy.

3.1.3 In addition to in-service load combinations, the design is to take into account loading conditions on the complete or partially complete structure during construction on a slipway or in a dock, launching, completion afloat, towing to site and anchoring to final position. Local environmental loads, appropriate to the season where applicable, are to be considered. The design for these conditions is to be such that the interim and subsequent compliance of the structure with the permanent design requirements is not impaired.

Table 2.3.1 Load factors and combinations for use with characteristic loads

Load Type	ULS (a)	ULS (b)	SLS	FLS	PLS Intact Accidental	PLS Intact Abnormal	PLS Post Damage
Permanent (P)	1,3 *see* Note 1	1,0	1,0	1,0	1,0	1,0	1,0
Live (L)	1,3 *see* Note 1	1,0	1,0	1,0	1,0	1,0	1,0
Deformation (D)	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Pre-stressing (D)	1,1/0,9 *see* Note 3	1,1/0,9 *see* Note 3	1,0	1,0	1,0	1,0	1,0
Environmental (E) *see* Note 2	0,7	1,3	1,0	1,0	1,0	1,0	1,0
Accidental (A)	—	—	—	—	1,0	—	—

NOTES
1. These load factors are the minimum allowed and are to be consistent with the selected recognised Concrete Structural Code or Standard. Some Codes or Standards allow reduced factors for well defined hydrostatic loads. Both of these factors are to be 1,0 where this leads to more onerous conditions.
2. Return periods for environmental loads are to satisfy Table 2.2.1.
3. Both coefficients are to be used in the analysis.

Section

Section 1
General

1.1 Structural design

1.1.1 The hull structure is to be capable throughout its design life, including construction and transit conditions, of withstanding all anticipated loads and deformations, both static and dynamic, with an adequate level of safety.

1.1.2 All relevant loads as defined in Chapter 2 and Pt 4, Ch 3, Ch 5 and Ch 10 are to be considered and the effects of partial and/or non homogeneous loading in oil bulk storage tanks are to be considered.

1.2 Symbols

1.2.1 The symbols used in the various formulae in this Chapter are defined as follows:

A_c = area of concrete section
A_s = area of tension reinforcement
b = width of member
b_t = width of the section at the centroid of the tension steel
d = effective depth
d_e = effective tension zone (1,5 x cover + 10 bar diameters)
E_c = short-term elastic modulus of concrete
E_s = modulus of elasticity for steel
f_{cu} = characteristic compression strength of concrete, based on cube tests
f_{pu} = characteristic strength of pre-stressing tendon
f_{tk} = characteristic tensile strength of the concrete
f_{tm} = mean tensile strength of the concrete
f_y = characteristic tensile strength of reinforcement steel
h = overall depth of the member
w = water pressure in cracks
x = depth of neutral axis
γ_f = partial safety factor for load
γ_m = partial safety factor for strength of materials
ε_i = strain at the level considered, calculated ignoring the stiffening effect of the concrete in the tension zone
ε_m = average strain at the level where cracking is being considered.

Section 2
Design requirements

2.1 Codes and Standards

2.1.1 Compliance with the various limit states given in Ch 1,3 is to be based on analyses for the load combinations given in Ch 2, 3. The resulting concrete section checks are to meet the requirements of a recognised National or International Code or Standard for structural concrete, *see* Pt 3, Appendix A for recognised Codes and Standards.

2.1.2 Not all recognised Codes and Standards adequately address all of the following:

- Shell and panel members typical of offshore structures.
- Panels subjected to both in-plane and out of plane loads (transverse shear).
- Assessment of transverse shear and resistance in directions non-orthogonal to the main axes.
- Multi axial stress in concrete.
- Crack control and liquid tightness.
- The effects of water pressure in cracks and pores on the applied loads and resistance.
- Fatigue of concrete, reinforcement and shear steel.
- Second order effects including panel buckling.
- Discontinuity regions, including complex nodes.

Where the selected Code or Standard does not adequately address all the above areas of design, it should be supplemented by suitable alternatives as agreed by Lloyd's Register (LR).

2.2 Design loads and design strength of materials

2.2.1 The design loads for a given limit state are obtained by multiplying the characteristic loads defined in Chapter 2 with the appropriate partial load factors given in Table 2.3.1 in Ch 2,3.

2.2.2 The characteristic strength of materials used in design is normally based on the compressive strength of the concrete, the yield or proof stress of the reinforcement or the ultimate strength of a pre-stressing tendon, below which not more than five per cent of all test results are expected to fall. The characteristic fatigue strength is normally based on the value below which not more than 2,5 per cent lie.

2.2.3 For analysis of sections, the design strength of steel for a given limit state is derived from the characteristic strength divided by the appropriate partial safety factor, γ_m. The factor (γ_m) is introduced to take account of differences between actual and laboratory values, local variations, and inaccuracies in assessment of the resistance of sections. It also takes account of the importance of the limit state being considered.

2.2.4 For analysis of sections, the design strength of concrete for a given limit state is derived from the *in situ* strength divided by the appropriate partial safety factor, γ_m. The *in situ* strength of the concrete is a function of the characteristic strength and is defined in the selected concrete structural Code or Standard.

2.2.5 It is vital that the material factor, γ_m, used in the design is consistent with the requirements of the selected concrete structural Code or Standard, for all materials and limit states.

■ *Section 3* **Analysis**

3.1 General

3.1.1 The methods of analysis used in assessing compliance with the requirements of the various limit states are to be based on as accurate a representation of the behaviour of the structure as is practicable. The analysis that is carried out to justify a design can be broken into two primary stages: analysis of the structure and analysis of the sections.

3.1.2 For analysis of the whole or part of the structure, and to determine force distributions within the structure, the properties of materials may be assumed to be those associated with their characteristic strengths, irrespective of which limit state is being considered. For section analysis of elements, the properties of the materials are to be those associated with their design strengths to the limit state being considered.

3.2 Analysis of structure

3.2.1 The analytical model may be based on non-linear or linear elastic theory. Where linear elastic analysis is used, the relative stiffnesses of members may be based on any of the following:

- The concrete cross-section: this is the entire plain concrete cross-section, ignoring the reinforcement.
- The homogenous or gross section: this is the entire concrete cross-section, including the reinforcement on the basis of modular ratio.

A consistent approach is to be used for all elements of the structure.

3.2.2 When cracking, creep or other causes lead to significant redistribution of loads, this should be considered. Alternatively, plastic methods of analysis such as yield line analysis may be used.

3.2.3 Values for elastic moduli, Poissons ratio, coefficient of temperature expansion, etc., used in the analysis may be based on the selected Code or Standard or knowledge of similar concretes. The values used in the analysis should be confirmed with tests on the concrete mixes used on site.

3.3 Analysis of sections

3.3.1 The element section analysis should consider the requirements of 2.1.2.

3.3.2 The following are to be addressed for the section analysis:

- Appropriate stress strain relationship for materials.
- Allowable compressive and tensile concrete strength limits.
- Material factors.
- Crack width formulae.
- Watertightness criteria.
- Fatigue strength relationships.

Detailed requirements for these items are to be covered in the recognised Codes or Standards, but further requirements are given in Section 4 for each of the limit states under consideration.

■ *Section 4* **Requirements for section analyses**

4.1 General

4.1.1 Although recognising that the selected concrete Code or Standard will have requirements for acceptance of design and detailing for the various limit states, the additional items outlined in this Section should also be complied with.

4.2 Analysis of sections for ULS

4.2.1 The material partial factor, γ_m, for reinforcement and pre-stressing strand should not be less than 1,15, irrespective of the Code or Standard selected.

4.2.2 In assessing panel members for buckling, adequate allowance is to be made for local and global geometric tolerances. Panels are to be assessed for a hydrostatic head based on the maximum still water draught together with the maximum wave pressures.

4.2.3 When considering shear close to supports, favourable arch effects are to be ignored when fluid pressure is acting in the cracks.

4.2.4 Where the shear failure mechanism is not well defined, the design is to be based on principal tensile stresses.

4.2.5 It is acceptable to include the positive effects of both compressive axial load and pre-stress when calculating shear resistance. However, it is considered that shear cracking prior to the ULS should be avoided and the appropriate method of calculation is to be adopted.

4.2.6 Where in-plane deformation forces (excluding pre-stressing) enhance the transverse shear capacity, they should be neglected. This may necessitate performing shear checks both with and without certain deformation loads, e.g., temperature.

4.2.7 Where temperature effects are significant and/or where lightweight concrete is used, the coefficient of temperature expansion, $\propto$, should be obtained by testing.

4.2.8 If the loading pattern of the cargo can result in significant torsion, these effects should be considered in the design.

4.3 Analysis of sections for SLS

4.3.1 Particular attention is to be given to design, detailing and construction of the large concrete areas in the splash zone.

4.3.2 The following crack width limits assume a formula similar to CEB/FIP recommendations. Equivalence should be demonstrated where the method of calculating crack widths is significantly different from that assumed.

4.3.3 Based on the normal serviceability condition (as defined in Table 2.3.1 in Chapter 2) the calculated crack widths should satisfy the requirements in Table 3.4.1. External to the hull, the splash zone should be considered to extend from 3,0 m below the lightship draught up to the deck level. For units subject to green seas on deck and frequent sea spray, the top deck surface should also be considered as the splash zone. The interior of ballast tanks are also to be designed on the same basis as the splash zone.

Table 3.4.1 Zonal crack width limits

	Crack width
Submerged zone	0,4 mm
Splash zone	0,2 mm
Atmospheric zone	0,4 mm

4.3.4 Allowance is to be made in the crack width calculations for deformation strains (temperature) to be concentrated at the cracked face of sections and increase the concrete crack width. The practice of using a strain twice the elastically calculated strain is acceptable.

4.3.5 For construction, transportation and installation, the crack widths shall not exceed 0,6 mm.

4.3.6 The minimum reinforcement quantities required to control cracking should be as given below, irrespective of the requirements of the selected Code or Standard. The calculations are for the area of reinforcement to be provided in each face and each direction:

(a) for concrete sections required to be watertight or oiltight:

$$A_s = \frac{f_{tm} + W}{f_y}\, b d_e$$

f_{tm}, f_y, w, b and d_e as defined in Section 1.2

$0,2 < d_e < 0,5\,(h - x)$

(b) for other sections:

$$A_s = \frac{kA_c}{f_y}\,(f_{tk} + w)$$

k = 0,4 for $h \leq 0,3$ m
k = 0,25 for $h \geq 0,8$ m
linear interpolation for $0,3 \text{ m} < h < 0,8$ m.

4.3.7 In areas of the structure adjacent to the sea which are intended to be watertight/oiltight, through-thickness cracks are to be avoided under normal serviceability conditions. In general, this is to be achieved by strictly maintaining a 'no tension' criterion for in-plane membrane forces for this condition.

4.3.8 A 'modified' serviceability condition shall be analysed for the extreme environmental condition as detailed in Note 1(b) of Table 2.2.1 in Chapter 2. This is to ensure that:

(a) the hull in contact with either sea-water and/or oil is to be designed so that, under any combination of loading, no tensile membrane stresses of a magnitude sufficient to cause cracking across the full thickness of the section can occur. Some flexural tensile stresses, however, may be unavoidable, but these are acceptable providing a compression zone of at least 200 mm is maintained;

(b) for the extreme environmental condition, the stress in the reinforcement is to be restricted to $0,85f_y$ and the compressive stress in the concrete to $0,5f_{cu}$.

4.3.9 Details of minimum cover requirements are given in Ch 4,2.7.

4.4 Analysis of sections for FLS

4.4.1 All stress variations imposed on the structure during its design life are to be considered in the fatigue evaluation. Account should be taken of the range of operating draughts and cargo filling/emptying cycles if significant.

4.4.2 A fatigue evaluation is to be carried out for the critical areas of the structure. It is expected this will be based on linear cumulative damage (Palmgren – Miner's Rule). The material partial factors and characteristic fatigue strength relationships (S-N curves) are to be appropriate for the selected Code or Standard, and should account for air and water locations, stress state and reinforcement diameter.

4.4.3 The dynamic behaviour of the unit is to be investigated to determine whether the increase in load effects due to dynamic amplification is important. If dynamic effects are considered significant then a response analysis is to be carried out.

4.4.4 The fatigue life factors of safety required are given in Table 6.5.1 in Pt 4, Ch 6 and range from 1 to 10, depending on location in the unit, the ability to inspect or repair and the consequences of failure. The factors chosen are to be agreed for areas assessed.

4.4.5 Where large compression or compression/tension stress ranges occur (e.g., hull bottom), consideration is to be given to appropriate design and detailing. Confinement reinforcement is to be provided to ensure ductile behaviour. As far as practicably possible, cycling into the tension range should be avoided.

4.4.6 It should be demonstrated that the design and detailing of penetrations, openings and access ways consider the increased cyclic nature of loading on floating concrete units compared to fixed offshore structures.

4.5 Analysis of sections for PCLS

4.5.1 In general, for accidental or abnormal loads, it should be documented that the strength or the ductility of the structure is sufficient for the applied loads.

4.5.2 For impact and explosive loads, account can be taken of increased material strength and modulus in accordance with the selected Code or Standard.

■ *Section 5* Other considerations

5.1 Installation layout and safety

5.1.1 In general, production units with crude oil bulk storage tanks are to be designed so that the separation of living quarters, storage tanks, machinery rooms, etc., are arranged in accordance with the requirements of Pt 3, Ch 3.

5.1.2 Special consideration may be given to concrete oil storage tanks fitted with suitable partial tank linings to prevent the risk of the escape of gas into adjacent spaces.

5.1.3 Concrete storage tanks used for the storage of liquefied gases, with or without insulation, are to be specially considered.

5.1.4 The general requirements for fire safety, hazardous areas and ventilation are to comply with Part 7. Safety and communication systems are to comply with the requirements of Pt 7, Ch 1.

5.2 Fire resistance

5.2.1 The required minimum period of fire resistance is to be stated in the design brief so that adequate protective measures may be taken by the selection of appropriate aggregates, reinforcement and cover. The selected Codes or Standards or specialist literature should be referred to for guidance.

5.2.2 Care should be exercised with certain lightweight aggregates. Where necessary the fire resistance of lightweight concretes is to be documented.

5.3 Corrosion protection

5.3.1 The requirements for the corrosion protection in Part 8 applicable to steel structures is also to apply to the exposed steel components of concrete units.

5.3.2 Reinforcement steel and pre-stressing tendons should either be actually isolated from the protected external steel, or the cathodic protection system designed to allow for current drain into the reinforcement as if it were electrically linked. In view of the practical problems of electrically isolating exposed and embedded steel, it is often preferable to consider them linked and make the necessary allowances in the cathodic protection.

5.4 Watertight/weathertight integrity

5.4.1 The general requirements for watertight and weathertight integrity given in Pt 4, Ch 8 are to be complied with.

5.4.2 Any proposals to deviate from the general requirements for steel units will be subject to special consideration.

5.5 Survey

5.5.1 The general requirements for surveys are to comply with Pt 1, Ch 2,3 and Chapter 3.

5.5.2 The Owner's planned procedure for the inspection of oil storage tanks and other enclosed spaces will be specially considered. Due account may be taken of the good performance to date of the use of concrete structures for the storage of hydrocarbons.

Section 1 Materials

1.1 General

1.1.1 Tests are to be made on all proposed materials prior to construction. The tests are to be carried out by an independent laboratory which is acceptable to Lloyd's Register (LR). Appropriate trials on proposed concrete and grout mixes will also be required. The testing is generally to be carried out in accordance with recognised National Codes or Standards, and is to be agreed with LR.

1.1.2 Certificates are to be submitted for all materials before work commences on site.

1.2 Cement

1.2.1 The following types of cement are acceptable:
- Ordinary Portland Cement.
- Rapid Hardening Portland Cement.
- Sulphate Resisting Cement.
- Low Heat Portland Cement.
- Portland Blast Furnace Cement.
- Portland Pozzalana Cement.
- Portland Pulverised Fuel Ash Cement.

1.2.2 The cement is to comply with the requirements of these Rules and with recognised National Codes or Standards. High-alumina cement is not to be used.

1.3 Cement replacements

1.3.1 Cement replacements, such as ground granulated blast furnace slag (g.g.b.f.s), pulverised fuel ash (p.f.a) or silica fume may be combined with Ordinary Portland Cement.

1.3.2 The proportions of the blend and the blended product itself are to comply with recognised National Codes or Standards. In particular circumstances blended proportions outside the range of normal Code requirements may be agreed with LR.

1.3.3 The percentage of silica fume in a blend is to be limited to 10 per cent by weight of cement.

1.4 Tricalcium aluminate

1.4.1 In order to limit potential sulphate attack, the tricalcium aluminate (C_3A) content of the cement is, in general, to be limited to 8 per cent, but in no case is it to exceed 10 per cent. The minimum C_3A content is to be 5 per cent.

1.5 Aggregates

1.5.1 Coarse and fine aggregates may be uncrushed and/or crushed natural and/or artificial mineral substances with particle sizes, shapes and other properties which have been accepted for use by testing and experience.

1.5.2 Marine aggregates are acceptable provided that the chloride salt content is at an acceptable level and the aggregate has a sufficiently low shell content. The total chloride content of the concrete mix arising from the aggregate, together with that from any admixtures and from any other source, is not to exceed 0,1 expressed as a percentage relationship between chloride ion and mass of cement in the mix.

1.6 Alkali-silica reaction

1.6.1 Some aggregates may be susceptible to deleterious reaction with alkalis normally present in the cement or from other sources including sea-water; this produces an expansive reaction which can cause cracking and disruption of the concrete.

1.6.2 It is recommended that, in order to minimise the risk of alkali-silica reaction, an aggregate of good performance record be used. Where this is not possible all aggregates are to be tested for potential reaction. The choice of aggregate is to be approved by LR and highly reactive aggregates will not be acceptable for use in sea-water. In some cases the aggregate will be acceptable if the following course of action is taken:

(a) Use of a low alkali (less than 0,6 per cent equivalent Na_2O) Portland Cement.

(b) Limit the alkali content of the concrete mix to 3 kg/m^3 of Na_2O equivalent.

(c) The use of g.g.b.f.s and p.f.a is recommended in some National Codes or Standards for reducing the alkali content of the mix. Agreement on their use will be subject to special consideration by LR and will also depend on the results of current test programmes.

1.7 Lightweight aggregate

1.7.1 Lightweight aggregates may be used, but the suitability of the aggregate selected for use is to be demonstrated.

1.8 Water

1.8.1 Water is to be clean and free from harmful matter, and is also to comply with National Codes or Standards. Sea-water is not to be used as mixing or curing water for any concrete containing reinforcement or pre-stressing tendons.

1.9 Admixtures

1.9.1 Air-entraining agents, workability agents and retarding agents may be used. The effects of over and under dosage should be established. Calcium chloride is not to be used or any admixtures containing more than 0,1 per cent chloride ion.

1.10 Reinforcing steel

1.10.1 Reinforcement is to comply with an appropriate recognised National Code or Standard. Storage, bending and acceptable welding practices are also to be in accordance with an approved standard agreed with LR.

1.11 Pre-stressing tendons

1.11.1 Pre-stressing tendons are to comply with appropriate recognised National Codes or Standards. Handling and tensioning procedures are also to be agreed. The time periods between installing strands, tensioning and grouting are to be agreed.

1.12 Pre-stressing ducts

1.12.1 Rigid or semi rigid watertight ducting may be used. Suitable procedures are to be developed and approved by LR for ensuring that the ducts are placed correctly, are watertight and kept free of debris and concrete during construction.

1.13 Grout (for pre-stressing tendons)

1.13.1 Ordinary Portland Cement is preferred. Sea-water is not to be used. Admixtures should be free from products liable to damage the steel or grout itself, such as chlorides, nitrates or sulphides. Expanding agents based on aluminium may be used provided it has been demonstrated to LR's satisfaction that the particular dose rate does not lead to stress corrosion.

1.13.2 The mix is to have appropriate fluidity and bleed properties. These should be verified by trials. For high strength concrete (>65 MPa) consideration should be given to increasing grout strength above the 40 MPa normally achieved.

1.13.3 Grouting procedures are to be developed and approved by LR. For long tendons and 'U' tendons, etc., procedures are to be verified with a prototype trial.

■ *Section 2* **Durability**

2.1 Zones of exposure

2.1.1 For durability, three zones of exposure are to be considered for concrete structures:

(a) Submerged zone: that part of the structure below the splash zone defined in item (b).
(b) Splash zone: all areas subject to wave action or sea spray, and is to be considered to extend 3,0 m below lightship draught and up to upper deck level, *see also* Ch 3,4.3.3.
(c) Atmospheric zone: that part of the structure above the splash zone.

2.2 Cement content

2.2.1 A minimum content of 400 kg/m^3 is to be used for the splash zone. In the submerged and atmospheric zones the minimum cement content is to be 320 kg/m^3 where the maximum size of aggregate is 40 mm, or 360 kg/m^3 where the maximum size of aggregate is 20 mm.

2.2.2 Cement contents in excess of 500 kg/m^3 should generally not be used.

2.3 Water/cement ratio

2.3.1 The water/cement ratio is to be below 0,45 in the submerged zone and below 0,4 for the splash zone (defined in Ch 3,4.3.3) and in the boundaries of oil storage tanks.

2.4 Minimum concrete strength

2.4.1 The minimum acceptable concrete strengths are indicated in Table 4.2.1.

2.4.2 Concrete tensile strength is also to be measured where required by the design Codes or Standards. For high performance concrete, direct tensile tests should be adopted.

2.5 Temperature

2.5.1 Consideration is to be given to the heat of hydration and shrinkage that may cause cracking.

2.5.2 In cold weather, precautions should be taken to prevent frost damage to the concrete.

2.5.3 Procedures are to be developed and agreed for hot weather concreting (ambient temperature >30°C) and cold weather concreting (ambient temperature <5°C) where applicable.

Table 4.2.1 Minimum acceptable concrete strengths

Zone	Exposure conditions	Concrete strength N/mm^2
Submerged	Directly exposed to salt water	40
	Directly exposed to crude oil or subject to severe abrasion	50
Splash	Directly exposed to salt water or salt-water spray	40
Atmospheric	Directly exposed to marine atmosphere	40
	Protected from direct exposure to marine atmosphere	30

NOTES
1. Concrete strength refers to the characteristic concrete strength obtained from testing standard 150 mm cubes of concrete at an age of 28 days.
2. The use of age factors is to be justified by testing.

2.6 Freezing and thawing

2.6.1 Parts of the structure that are subjected to freezing and thawing are to have adequate frost resistance. For severe situations, air entrainment is to be used, and reference is to be made to relevant standards for details of quality of air and spacing factors.

2.6.2 Freeze/thaw cycles may require special consideration for the storage of LPG and LNG in bulk depending upon tank arrangements and/or heating systems.

2.7 Concrete cover reinforcement

2.7.1 The nominal cover is to be not less than that shown in Table 4.2.2 or in accordance with the following, whichever is the greater:
(a) 1,5 times the nominal maximum size of aggregate.
(b) 1,5 times the maximum diameter of reinforcement or pre-stressing tendons.
(c) For bundled bars, the greater of either 1,5 times the diameter of the largest bar in the bundle or the diameter of the equivalent bar, but not more than 100 mm. The equivalent bar is a single bar having the same cross-sectional area as the bundle of bars.

2.7.2 For the concrete given in this Section, the permeability is to be less than 10^{-12} m/sec.

2.7.3 For certain types of structural configuration additional cover may be required to prevent deterioration due to acidic water or hydrogen sulphide gas.

Table 4.2.2 Nominal concrete cover in relation to zones of exposure

Zone	Nominal cover, mm, *see* Note	
	Reinforcement	Pre-stress
Submerged	40	85
Splash	50	95
Atmospheric (subjected to spray)	50	95
Atmospheric (general)	40	85

NOTE
Nominal cover is defined as the cover to the shear reinforcement.

2.8 Concrete protection against chemical attack

2.8.1 For oil storage tanks, the possible attack by hydrogen sulphide, organic acids, etc., is to be considered.

2.8.2 Where flue gases are used as the inerting medium in tanks, consideration is to be given to the concrete being attacked by CO_2 and/or SO_2 in hot, high humidity conditions. This will need to be addressed on a case-by-case basis.

2.8.3 Where sufficiently high concentrations of chemicals may occur which could result in chemical attack, consideration is to be given to providing a suitable chemical resistant liner or partial liner.

Rules and Regulations for the Classification of Offshore Units

Part 10
Ship Units

July 2014

Lloyd's Register

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■ *Section 1* General

1.1 Application

1.1.1 This Chapter outlines the hull structural design requirements of ship units with hull construction in steel engaged in production and/or cargo storage/offloading while permanently moored at offshore locations. For the purposes of this Part, the term ‘cargo’ refers to crude oil, liquefied gas, condensate, methanol, process chemicals including refrigerants and by-products of the production process.

1.1.2 The Rules are also applicable to units which normally operate while moored at offshore locations, but which are disconnectable in order to avoid extreme environmental conditions or hazards, *see also* Pt 4, Ch 3,4.

1.1.3 Units which operate as shuttle tankers will normally be assigned class in accordance with the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.1.4 Hull strength, scantlings and arrangements for ship units are to comply with Part 10. Reference is also made to the LR ShipRight Procedure for Ship Units.

1.1.5 All aspects which relate to the specialised offshore function of the unit are to be considered on the basis of this Chapter and the additional requirements related to the design arrangements and functions of drilling and production units given in Pt 3, Ch 2 and 3 are to be complied with.

1.1.6 The scantlings and arrangements of units with a limited number of tanks for the storage of flammable liquids having a flash point not exceeding 60°C (closed-cup test) will be specially considered.

1.1.7 The class notations and descriptive notes applicable to units classed in accordance with these Rules are to be in accordance with Pt 1, Ch 2 and Pt 3, Ch 3,1, to which reference should be made.

1.1.8 Additional requirements related to the design function of the unit are given in Part 3.

1.1.9 Turret structures, mooring arms and yoke structures, etc., are to comply with the requirements of Section 9 and Pt 3, Ch 13.

1.1.10 Units with a process plant facility which comply with the requirements of Pt 3, Ch 8 will be eligible for the assignment of the special features class notation **PPF**.

1.1.11 Units with a drilling plant facility which comply with the requirements of Pt 3, Ch 7 will be eligible for the assignment of the special features class notation **DRILL**.

1.1.12 The structural design of integral tanks for the storage of condensates is to comply with the requirements in this Part outlined for cargo tanks and other tanks designed for liquid filling. The density of the condensate is not to be taken as less than the minimum density values, as defined in Table 2.1.1 in Chapter 2, for strength and fatigue assessments.

1.1.13 The structural design of integral tanks for the bulk storage of liquid chemicals is to comply with the requirements in this Part outlined for cargo tanks and other tanks designed for liquid filling. The following requirements are also to be complied with:

(a) The density of the liquid chemicals is not to be taken as less than the minimum density values, as defined in Table 2.1.1 in Chapter 2, for strength and fatigue assessments.
(b) Consideration is to be given to the nature of the chemicals being stored, including their corrosiveness, reactivity and flammability. Arrangements are in general to comply with the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code), as interpreted by LR.
(c) Corrosion rates will be specially considered on the basis of the corrosiveness and reactivity of the stored chemical with the tank material.

1.1.14 The structural design of independent tanks for the bulk storage of liquid chemicals is to comply with the requirements of Pt 11, Ch 4 and 1.1.13 (b) and (c).

1.1.15 Ship units engaged in the production, storage and offloading of liquefied gases at a fixed location are to comply with Part 11 and other relevant Parts in addition to the requirements of this Part.

1.2 Definitions

1.2.1 General definitions are given in Pt 1, Ch 2,2 and Pt 4, Ch 1,5.

1.2.2 Additional definitions relevant to Part 10 are given below:

T_{SC} = deep load draught, in metres, is the maximum draught on which the scantlings are based

T_{LT} = light load draught, in metres, is the minimum draught on which the scantlings are based.

1.2.3 **Moderate service**. A Moderate service is one where the site-specific responses of the vessel are less than or equal to the responses in unrestricted worldwide transit. The following responses are to be compared:

(a) Hull girder vertical wave bending moment.
(b) Relative wave elevation.
(c) Vertical acceleration.
(d) Roll angle.

1.2.4 **Harsh service**. A Harsh service is one which does not satisfy the definition of a Moderate service.

1.2.5 **Transit**. Any voyage of the unit, self-propelled or unpropelled, from one geographical location to another. The following are considered transit conditions:

(a) **Delivery voyage**. Delivery voyage of a unit along a defined route from a shipyard or field to the operating site at which the **OI** class notation is assigned. The delivery voyage is typically scheduled for restricted sea states.
(b) **Restricted service area transit**. Transit of a unit at any time across a restricted service area. Voyages of this nature may be carried out by disconnectable units that sail away within a defined service area either to avoid approaching heavy weather and/or to return to a dry dock for inspection.
(c) **Unrestricted worldwide transit**. Transit of a unit at any time across any sea area in the world. Voyages of this nature may be carried out by disconnectable units that sail away either to avoid approaching heavy weather and/or to return to a dry dock for inspection.

1.3 Application of transit conditions

1.3.1 All units are to be assessed for the delivery voyage. This is to ensure that the unit arrives fit for entry into class at the operating field where the **OI** class notation is assigned. The Owner is to define the wave environment and the maximum transit speed for the delivery voyage.

1.3.2 Disconnectable units are to be assessed for unrestricted worldwide transit, in which case the delivery voyage need not be assessed. The Owner is to define the maximum transit speed for disconnected service. For unrestricted worldwide transit, the loads defined in Chapter 2,7 are to be used. Alternatively, at the request of the Owner, the unit may be assessed to transit within a restricted service area. In this case, a service restriction will be placed on the unit and recorded in theclass notation, see 1.2.5(b). The Owner is to define the wave environment for the restricted service area.

■ *Section 2*
Information required

2.1 General

2.1.1 Sufficient plans and supporting data are to be submitted to enable the design of the structure to be assessed. The plans are also to be suitable for use during construction, survey and inspection/maintenance of the unit.

2.1.2 Plans are to be submitted in triplicate, but generally only one copy of supporting design documentation and calculations is required. Plans and supporting documentation should be submitted and approved prior to commencement of construction.

2.1.3 Plans are to contain all necessary information fully to define the structure, including construction details, materials, welding and loads imposed on the structure by equipment and systems, as appropriate.

2.1.4 A copy of the Construction Booklet, Operations Manual and In-Service Inspection Plan must be submitted for class approval, incorporating the final approved revisions of relevant plans and documentation, *see* Pt 1, Ch 3,1.6 and Pt 3, Ch 1.

2.1.5 Plans are to include information related to the renewal thickness as specified in Section 13.

2.1.6 A general list of plans and supporting calculations is given in 2.2. Detailed plan lists can be found in the relevant Sections of the Rules listed below:

- Part 3, Chapter 1, Section 5, (Rules for Ships): Basic Hull structure;
- Part 1, Chapter 3, Section 1.6: Planned survey programme;
- Part 3, Chapter 1, Section 2: General, OIWS, Construction Booklet;
- Part 3, Chapter 3, Section 1.6: Production and oil storage units (general);
- Part 3, Chapter 3, Section 2.1: Production and oil storage units (structure);
- Part 3, Chapter 8, Section 1.11: Process plant facility;
- Part 3, Chapter 9, Section 1.3: Dynamic positioning system;
- Part 3, Chapter 10, Section 1.4: Positional mooring system;
- Part 4, Chapter 1, Section 4: General structure;
- Part 4, Chapter 6, Section 5.2: Helideck;

- Part 4, Chapter 7, Section 1.2: Watertight/weathertight integrity;
- Part 8, Chapter 1, Section 3: Corrosion control.

2.2 Plans and supporting calculations

2.2.1 In general, plans covering the following items are to be submitted:

(a) main scantling plans:
- midship section showing longitudinal and transverse structural members;
- construction profiles/plans showing all main longitudinal structural elements along the unit's length;
- shell expansion;
- main oil-tight and watertight transverse bulk-heads including primary support members.

(b) loading guidance information:
- preliminary loading manual;
- final loading manual;
- details of the design basis;
- test conditions for the loading instrument.

(c) detailed construction plans:
- cargo tank construction plans showing the variations in detail arrangements and scantlings of transverse primary support members;
- fore end;
- aft end;
- machinery spaces;
- deck-houses and superstructures;
- helideck;
- ice strengthening;
- materials and grades;
- plans showing the proposed fatigue factors of safety for each part of the structure.

(d) detail design plans, except where the information is already included on plans listed in (a) and (c):
- hull penetration plans;
- welding;
- bilge keels;
- booklet of standard design details;
- pillar and girder support arrangements for decks;
- access arrangements;
- details and arrangements of openings and attachments to the hull structure for means of access for inspection/maintenance purposes.

(e) plans detailing support structures, except where the information is already included on plans listed in (a) to (d):
- masts, derrick posts, cranes and crane pedestals, flare towers and heavy equipment;
- towing equipment;
- other deck equipment or fittings;
- machinery seatings;
- riser support structures;
- rudder stock, tiller and steering nozzles;
- stern frame and propeller brackets.

(f) The following supporting documents are to be submitted:
- general arrangement;
- capacity plan;
- lines plan or equivalent;
- dry-docking plan, where developed;
- freeboard plan or equivalent, showing freeboards and items relative to the conditions of assignment;
- corrosion control scheme;
- towing and anchoring arrangements;
- watertight subdivision;
- welding procedures.

2.3 Plans and information to be supplied on board the unit

2.3.1 One copy of each of the following documents:

(a) main scantling plans, as given in 2.2.1(a);
(b) one copy of the final approved loading manual;
(c) one copy of the final loading instrument test conditions;
(d) detailed construction plans, as given in 2.2.1(c);
(e) welding;
(f) details of the extent and location of higher tensile steel, together with details of the specification and mechanical properties, and any recommendations for welding, working and treatment of these steels;
(g) details and information on use of special materials, such as aluminium alloy, used in the hull construction;
(h) details of the corrosion control system;
(j) operations manual.

Plans are to indicate the new-building and renewal thickness for each structural item.

■ *Section3* Materials

3.1 General

3.1.1 Steel should be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) or other acceptable standards. The strength and grades (notch toughness) of steel required will depend on the following:

(a) design temperature;
(b) thickness;
(c) substance being stored/processed;
(d) structural category;
(e) location.

3.1.2 Material classes and steel grades should comply with Pt 4, Ch 2 unless indicated otherwise in this Section. Materials for the hull structure of ship units engaged in the production, storage and offloading of liquefied gases at a fixed location are also to comply with Pt 11, Ch 4 and 6.

3.1.3 Critical joints which depend upon the transmission of tensile stress through the thickness perpendicular to the plate surface of one of the members are to be avoided wherever possible. Where the stress perpendicular to the plate surface exceeds 50 per cent of the Rule permissible stress and the thickness exceeds 15,0 mm, plate material with suitable through-thickness properties as required by Ch 3,8 of the Rules for Materials is to be used. For certain critical joints with a restricted load path, these criteria would be subject to special consideration, for example, mooring fairlead attachments and anchor line or hawser connections.

3.1.4 Steel grades for special and primary structural components with thickness in excess of the limitations of Chapter 3 of the Rules for Materials and Table 2.4.1 in Pt 4, Ch 2 will be specially considered.

3.1.5 Where attachments/pads are located on special or primary components which are subjected to high stresses, the attachment is to be of the same material as the plating to which it is attached, with welding to the same standard as the main structure.

3.1.6 Steel having a specified minimum yield stress of 235 N/mm^2 is regarded as normal strength hull structural steel. Steel having a higher specified minimum yield stress is regarded as higher strength hull structural steel.

3.1.7 For the determination of hull girder section modulus, where higher strength hull structural steel is used, a higher strength steel factor, *k*, is given in Table 1.3.1.

Table 1.3.1 Values of *k*

Specified minimum yield stress, N/mm^2	*k*
235	1,00
265	0,93
315	0,78
340	0,74
355	0,72
390	0,68

NOTE
Intermediate values are to be calculated by linear interpolation.

■ *Section 4* Structural arrangement

4.1 General

4.1.1 General requirements regarding location and separation of spaces, layout and arrangement of primary structural components are given in Pt 3, Ch 3,1.4. Detailed requirements are given in Ch 1,4.

4.1.2 Overall subdivision of the hull should take full account of strength and stability requirements and minimise the consequences of damage, pollution risk and loss of the unit in the event of damage. Additional subdivision of the hull may be required to account for ballast water needed to control hull stresses and for the storage of process-related liquids.

4.1.3 The Marine Environment Protection Committee of the International Maritime Organization (IMO) has decided that tankers which are used solely for storage and production of oil, and are moored at a fixed location except in extreme environmental or emergency conditions, are not required to comply with all the provisions of the *International Convention for the Prevention of Pollution from Ships, 1973*, as modified by the Protocol of 1978 relating thereto (hereinafter referred to as MARPOL) unless specified in whole or in part by the relevant National Authority. Therefore, double hulled construction would not be necessary unless specified by the National Authority. When MARPOL is invoked for ship units, normally also the interpretations for ship units defined in MEPC Circ. 139(53) are applicable, but this is subject to adoption of MEPC Circ.139 by the National Authority.

4.1.4 Account should be taken of the interaction between structural strength and stability. Particular consideration should be given to tank dimensions with respect to tank inspection/ maintenance requirements and sloshing/free surface effects for partially filled tanks. Intact and damage stability should comply with applicable National Authority requirements.

4.1.5 Self-propelled floating units should meet the requirements of the *International Convention on Load Lines 1966* (hereinafter referred to as ICLL). Units which do not engage in international voyages, except for transfers between fabrication sites and the installation voyage to the designated site, should have marks which indicate the maximum permissible draught as calculated under the ICLL Requirements.

4.1.6 General requirements for deck layouts/arrangements are given in Pt 3, Ch 3,1.4 and Part 7.

4.1.7 Deck-house superstructures may be located forward or aft of the cargo storage tanks. Living quarters, lifeboats and other means of evacuation should be located in non-hazardous areas and be protected and separated from production, storage and turret areas. As a minimum, the arrangement and separation of living quarters, storage tanks, machinery rooms, etc., should be in accordance with the *International Convention for the Safety of Life at Sea, 1974* and its Protocol of 1978 (hereinafter referred to as SOLAS). Where the superstructure is located forward of the cargo tank area, arrangements should provide a suitable level of separation and protection.

4.1.8 The location of the topsides facilities deck and structural arrangements should comply with Pt 3, Ch 3,3.1.4, Pt 3, Ch 3,7 and Ch 3,8 and Part 7 as relevant, together with applicable National Authority Codes and Standards regarding dangerous zones or divisions and provision of adequate access. Areas and compartments of floating units are defined as hazardous zones according to their proximity to equipment, pipes or tanks containing certain flammable liquids and whether these fluids are at temperatures approaching or exceeding their flashpoints, *see* Pt 7, Ch 2.

4.1.9 Alternative arrangements which are proposed as being equivalent to the Rules will receive individual consideration, taking into account any relevant National Authority requirements.

4.1.10 Reference should also be made to SOLAS and applicable amendments.

4.1.11 The number of openings in watertight bulkheads is to be kept to a minimum. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

4.2 Arrangement for turrets

4.2.1 A cofferdam or equivalent is to be arranged between cargo bulk storage tanks and the turret casing or turret equipment spaces internal to the hull. The scantlings and testing requirements are to comply with Rule requirements for cofferdam bulkheads. Suitable corrosion protection, drainage and gas freeing arrangements are to be provided to such spaces. A pump-room, void space or water ballast tank will be accepted in lieu of a cofferdam.

4.2.2 The bulkheads bounding the turret space are to comply with the scantling requirements for side shell structure and for bulkheads. Blast loading is also to be considered.

4.3 Structural continuity

4.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

4.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

■ *Section 5* Structural design – New-build units

5.1 General

5.1.1 This Section outlines the hull structural calculation and analysis requirements for new-build ship units engaged in production and/or oil storage/offloading moored at offshore locations. Requirements are given for permanently moored units and disconnectable units.

5.1.2 The hull structure is to be designed to withstand the static and dynamic loads imposed on the structure in all operating conditions and all anticipated pre-service conditions. All relevant loads as defined in Pt 4, Ch 3 are to be considered, including the effects of partial and/or non-homogeneous loading in cargo bulk storage tanks. When considering the design loading conditions, the Owner/ designer is to take account of the requirements for on-station tank inspection/maintenance. Loads during construction, installation and decommissioning, towing/transportation should be considered, as applicable. Reference is also made to the LR ShipRight Procedure for Ship Units.

5.1.3 The assessment of environmental loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the hull at the site-specific location, taking into account the following service-related factors:

(a) site-specific environmental loads including relevant non-linear effects;
(b) mooring system and riser loads;
(c) unit orientation and wave loading directions;
(d) long-term service effects at a fixed location;
(e) range of tank loading conditions, including empty tanks required for on-station surveys;
(f) potential relocations if applicable.

5.1.4 For Moderate service, the site-specific loads can be used. The loads for unrestricted worldwide transit from Chapter 2 may be used at the Owner's discretion. For Harsh service the site-specific loads must be used. Where the unit is intended for operation at more than one location, the most severe design criteria are to be applied. Where the **ShipRight RBA** notation is assigned, the site-specific loads must be used.

5.1.5 On-site tank inspections/maintenance are to be restricted to reasonable weather as defined in Pt 1, Ch 2. For design purposes, the permissible still water bending moments and shear forces for tank inspection/maintenance conditions may be based on 100-year return period seasonal site criteria. Tank inspection/maintenance conditions are to be included in the unit's loading manual and the limiting environmental criteria are to be defined in the Operations Manual.

5.1.6 Where it is intended to dry-dock a unit during its service life, this is to be taken into account at the design stage and the docking condition is to be submitted to LR for approval. The bottom structure should be suitably strengthened to withstand the bearing pressures and loads imposed by dry-docking.

5.1.7 Disconnectable units, as defined in 1.1.2, will remain in class in the sail-away condition and the loading conditions are to be submitted for approval.

5.1.8 The hull structure of is to be assessed for applicable transit conditions in accordance with Chapter 1,1.3.

5.1.9 The general requirements for investigating accidental loads are defined in Pt 4, Ch 3,4.16. Collision loads against the hull structure will normally cause only local damage to the hull structure and consequently need not be investigated from the overall strength aspects.

5.1.10 Structural strength and fatigue analyses are generally required to verify that hull structure and critical structural connections, when subjected to the site-specific load combinations and other relevant load combinations, are suitable for the required service life on location.

5.1.11 Hull integration structure in way of moorings, topsides and other concentrated loads is to be verified by direct calculations. Permissible stress levels are to be in accordance with Chapter 3 or Pt 4, Ch 5.

5.1.12 Where permitted by the relevant National Authority, single hulled units may be accepted.

5.1.13 Sufficiently robust underdeck reinforcement should be provided in the way of the welded connections of the topsides support structure to the main hull. The support structures should be aligned with the primary members of the hull structure.

5.1.14 Hull structure and mooring integration structures: for disconnectable units at locations exposed to cyclones, the environmental loads when disconnected are not to be taken less than required by Chapter 2 for unrestricted worldwide transit.

5.2 Hull scantlings

5.2.1 The longitudinal strength of the unit is to comply with the requirements of Chapter 3. The total stresses from the combined effects of site-specific wave loads, still water loads, mooring loads, etc., are not to exceed permissible values.

5.2.2 When the site-specific wave bending moments and shear forces are below the values for unrestricted worldwide transit, the site-specific values may generally be used for design, *see* 5.1.4. However, in no case are the site-specific wave bending moments and shear forces to be taken as less than 50 per cent of the value for unrestricted worldwide transit.

5.2.3 The requirement for hull girder inertia given in Chapter 3 is to be complied with.

5.2.4 The strength of the unit in the transit condition and in the site-specific installation condition is to be investigated and submitted to LR for approval.

5.2.5 For initial design purposes, site-specific environmental factors are given in Ch 2,3.3 with the associated Dynamic Load Combination factors (DLCF) given in Ch 2,7 for the unrestricted worldwide transit condition and Ch 2,8 for the On-site Operational condition.

5.2.6 For the final design, the loads derived in accordance with the LR ShipRight Procedure for Ship Units must be used.

5.3 Strength analysis

5.3.1 The scantlings of the primary structure of the cargo bulk storage tank area are to be verified by direct calculations based on a three-dimensional finite plate element analysis carried out in accordance with the LR ShipRight Procedure for Ship Units.

5.3.2 The corrosion additions are to be determined as described in Section 12.

5.4 Fatigue analysis

5.4.1 The fatigue assessment of the hull structure of ship units is to be verified in accordance with the LR ShipRight Procedure for Ship Units.

5.4.2 In all cases, the fatigue assessment should address the primary hull structure connections, primary topside support structure and hull integration, together with other primary structure connections subject to significant dynamic loading. Account should be taken of all important sources of cyclic loading, *see also* Pt 4, Ch 5,5.2.

5.4.3 Fatigue calculations for the mooring structures and integration of the mooring system within the unit's hull structure are also to be carried out, *see* Pt 3, Ch 10.

5.4.4 The turret-bearing support structures are to be assessed for fatigue damage due to cyclic loading in accordance with Pt 4, Ch 5,5.

5.4.5 The general requirements for fatigue design and factors of safety on fatigue life for supporting structures to drilling and process plant, flare towers, derricks, cranes and crane pedestals and mooring structures are to comply with Pt 4, Ch 5,5.

5.4.6 The minimum design fatigue life for structural elements should not be less than the intended field life, but in general should not be less than 25 years. The cumulative damage ratio for individual components should take account of the degree of redundancy and accessibility of the structure and also the consequence of failure, *see also* Pt 4, Ch 5,5.

■ *Section 6* Structural design – Tanker conversions

6.1 General

6.1.1 This Section outlines the hull structural calculations and analysis requirements for tanker conversions engaged in production and/or cargo storage/offloading moored at offshore locations. Requirements are given for permanently moored units and disconnectable units. At the Owner's request, the requirements given in Section 5 may be applied instead of the requirements given in this Section.

6.1.2 The hull structure is to be designed to withstand the static and dynamic loads imposed on the structure in all operating conditions and all anticipated pre-service conditions. All relevant loads as defined in Pt 4, Ch 3 are to be considered and the effects of partial and/or non-homogeneous loading in cargo bulk storage tanks are to be considered. When considering the design loading conditions, the Owner/designer is to take account of the requirements for on-station tank inspection/maintenance. Loads during construction, installation and decommissioning, and towing/transportation should be considered, as applicable. Reference is also made to the LR ShipRight Procedure for Ship Units.

6.1.3 The assessment of environmental loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the hull at the site-specific location, taking into account the following service-related factors:

(a) Site-specific environmental loads including relevant non-linear effects.
(b) Mooring system and riser loads.
(c) Unit orientation and wave loading directions.
(d) Long-term service effects at a fixed location.
(e) Range of tank loading conditions, including empty tanks required for on-station surveys.
(f) Potential relocations if applicable.

6.1.4 For Moderate service, the site-specific loads can be used. The loads for unrestricted worldwide transit service from Chapter 2 may be used at the Owner's discretion. For Harsh service, the unit is to be reassessed as for a new build. Where the unit is intended for operation at more than one location, the most severe design criteria are to be applied. Where the **ShipRight RBA** notation is assigned, the site-specific loads must be used.

6.1.5 Where a unit is intended to operate in Moderate Environments, the existing scantlings of the hull need not be re-assessed, subject to the following conditions:

- the vessel was built under the survey of a member of IACS before conversion;
- the vessel has been maintained in Class by a member of IACS before conversion;
- CAP assessment 1 or 2 assigned;
- all necessary repairs are made to delete any Conditions of Class;
- the in-service corrosion margins applied after conversion are the same as those applicable as a trading tanker;
- LR Transfer of Class (TOC) procedures are complied with if the vessel is transferring Class to LR;
- a Special Survey is conducted during the conversion;
- the loading on the structure is not increased;
- the structure is not changed;
- the vessel was originally approved for worldwide service.

Where these conditions are not met (for example, turret integration structure, supporting structure under topsides and crane pedestals), the structure is to be re-assessed in accordance with Section 5.

6.1.6 For Moderate service further to the reassessment criteria specified in 6.1.5, the hull scantlings are to be reassessed where the **ShipRight RBA** notation is assigned. If the structure is modified or the loading changed then the hull scantlings affected by these changes should be reassessed. Hull scantlings of a conversion may need to be reassessed for the following reasons:

- integration of the mooring system of an internal turret;
- loads from topsides equipment on the upper deck;
- redefinition of loading limitations assigned as a tanker (for example, changes to permissible still water bending moments and shear forces) where required for unit-specific loading conditions;
- measured corrosion found to be in excess of that permitted for a trading tanker.

6.1.7 On-site tank inspections/maintenance are to be restricted to reasonable weather as defined in Pt 1, Ch 2. For design purposes, the permissible still water wave bending moments and shear forces for tank inspection/maintenance conditions may be based on the existing assigned permissible still water values. Where the existing assigned permissible still water values are insufficient, wave bending moments and shear forces may be based on 100-year return period seasonal site criteria and still water permissible values adjusted accordingly. Tank inspection/maintenance conditions are to be included in the unit's loading manual and the limiting environmental criteria are to be defined in the Operations Manual.

6.1.8 Where it is intended to dry-dock a unit during its service life, this is to be taken into account at the design stage and the docking condition is to be submitted to LR for approval. The bottom structure should be suitably strengthened to withstand the bearing pressures and loads imposed by dry-docking.

6.1.9 Disconnectable units, as defined in 1.1.2, will remain in class in the sail-away condition and the loading conditions are to be submitted for approval.

6.1.10 The hull structure is to be assessed for applicable transit conditions in accordance with Chapter 1,1.3.

6.1.11 The general requirements for investigating accidental loads are defined in Pt 4, Ch 3,4.16. Collision loads against the hull structure will normally cause only local damage to the hull structure and consequently need not be investigated from the overall strength aspects.

6.1.12 Structural strength and fatigue analyses are generally required to verify that hull structure and critical structural connections, when subjected to the site-specific load combinations and other relevant load combinations, are suitable for the required service life on location.

6.1.13 Hull integration structure in way of moorings, topsides, crane pedestals, flare towers and other concentrated loads is to be verified by direct calculations. Permissible stress levels are to be in accordance with Pt 4, Ch 5.

6.1.14 The detailed scope of analysis required for hull structural assessments of tanker conversions will be considered on a case-by-case basis, *see* 6.2.

6.1.15 Where permitted by the relevant National Authority, single hulled units may be accepted.

6.1.16 Sufficiently robust underdeck reinforcement should be provided in way of the welded connections of the topsides support structure to the main hull. Special attention should be given to alignment of primary members.

6.1.17 For disconnectable units at locations exposed to cyclones, the environmental loads when disconnected are not to be taken less than required by Chapter 2 for unrestricted worldwide transit service for the assessment of structures required by 6.1.6.

6.1.18 For units permanently moored by the stern, the structural arrangements and scantlings of all exposed structure located in the aft end of the unit are to be specially considered. The strengthening of the bottom structure is to be specially considered.

6.2 Hull scantlings

6.2.1 Hull scantlings are to be re-assessed in accordance with the requirements for new-build units, *see* 5.3, whenever any of the following apply:

(a) The unit is to be deployed in harsh service;
(b) The total hull girder bending moments (hogging and sagging) approved prior to conversion, i.e., vertical wave bending moment + permissible still water vertical bending moment, are exceeded; or
(c) The total hull girder shear forces (positive and negative) approved prior to conversion, i.e., vertical wave shear force + permissible still water vertical shear force, are exceeded.

6.2.2 When the site-specific wave bending moments and shear forces are below the values for unrestricted worldwide transit, the site-specific values may generally be used for design, *see* 6.1.4. However, in no case are the site-specific wave bending moments and shear forces to be taken as less than 50 per cent of the value for unrestricted worldwide transit.

6.2.3 If the environmental factors, as defined in Ch 2,3.1, calculated for the hull girder bending moments ($f_{\text{Env-Mwv}}$ or $f_{\text{Env-Mwv-h}}$) or shear force ($f_{\text{Env-Qwv}}$) exceed 1,0, then the hull scantlings are to be re-assessed in accordance with the requirements for new-build units, *see* 5.3.

6.2.4 The strength of the unit in the transit condition and in the site-specific installation condition is to be investigated and submitted to LR for approval.

6.2.5 Where the conversion includes provision for an internal turret mooring system, the effects of such openings and reinforcement structure on hull girder strength should be evaluated.

6.2.6 It is recommended that, in general, corrosion additions are to be determined based on Section 12; however, consideration will be given to alternative proposals submitted by the Owner.

6.3 Fatigue analysis

6.3.1 The fatigue assessment of the hull structure of ship units is to be verified in accordance with the LR ShipRight Procedure for Ship Units.

6.3.2 In all cases, the fatigue assessment should address the primary hull structure connections, primary topside support structure and hull integration, together with other primary structure connections subject to significant dynamic loading. Account should be taken of all important sources of cyclic loading. *See also* Pt 4, Ch 5,5.2.

6.3.3 Fatigue calculations for the mooring structure and integration of the mooring system within the unit's hull structure are also to be carried out, *see* Pt 3, Ch 10.

6.3.4 The turret-bearing support structures are to be assessed for fatigue damage due to cyclic loading, in accordance with Pt 4, Ch 5,5.

6.3.5 The general requirements for fatigue design and factors of safety on fatigue life for supporting structures to drilling and process plant, flare towers, derricks, cranes and crane pedestals and mooring structures are to comply with Pt 4, Ch 5,5.

6.3.6 Fatigue calculations for installations based on tanker conversions should take into account the fatigue damage accumulated as a trading tanker prior to conversion.

6.3.7 The design corrosion additions are to be deducted from the scantlings, measured at the time of conversion, as described in the LR ShipRight Procedure for Ship Units. This is to ensure the calculation of fatigue damage after conversion accounts for any reduction in the as-built scantlings. The analysis is required to verify that the remaining fatigue life of the converted hull structure is compatible with the required service life on location, *see also* 6.3.8.

6.3.8 The minimum design fatigue life (after accounting for fatigue damage accumulated as a trading tanker prior to conversion) for structural elements should not be less than the intended field life, but should not be less than 5 years. The cumulative damage ratio for individual components should take account of the degree of redundancy and accessibility of the structure and also the consequence of failure, *see also* Pt 4, Ch 5,5.

6.3.9 The in-service Class survey reports for the vessel from build until conversion are to be submitted to LR for review. All critical locations in the existing structure which may be prone to fatigue cracking are to be examined by MPI or other suitable NDE methods at the time of conversion. The critical locations are to be selected based on the previous service history of the vessel and the recommendations in the LR ShipRight Procedure for Ship Units. A detailed NDE plan is to be submitted for approval.

6.4 Strength analysis

6.4.1 Requirements for direct calculations are given in the LR ShipRight Procedure for Ship Units.

■ *Section 7* Redeployment of existing units

7.1 General

7.1.1 If the 100-year environmental loads are larger than those of the previous geographical location then the requirements of Section 6 are to be applied for the redeployment of existing ship units.

7.2 Fatigue analysis

7.2.1 Fatigue calculations should take into account the fatigue damage accumulated prior to redeployment.

7.2.2 The design corrosion additions are to be deducted from the scantlings measured at the time of redeployment, as described in the LR ShipRight Procedure for Ship Units. This is to ensure the calculation of fatigue damage after redeployment accounts for any reduction in the as-built scantlings. The analysis is required to verify that the remaining fatigue life of the hull structure is compatible with the required service life on location, *see also* 6.3.8.

■ *Section 8* Structural idealisation

8.1 General

8.1.1 General structural idealisation is covered in Pt 4, Ch 3,3. Additional approaches relevant to Part 10 are given in this Section.

8.2 Mixed steel grades

8.2.1 When a stiffener is of a higher strength material than the attached plate, the yield stress used for the calculation of the section modulus requirements in Chapter 3 is, in general, not to be greater than 1,35 times the minimum specified yield stress of the attached plate. If the yield stress of the stiffener exceeds this limitation, the following criterion is to be satisfied:

$$\sigma_{yd\text{-}stf} \leq (\sigma_{yd\text{-}plt} - |\sigma_{hg}|)\frac{Z_{net\text{-}plt}}{Z_{net}} + |\sigma_{hg}| \quad \text{N/mm}^2$$

where

$\sigma_{yd\text{-}stf}$ = specified minimum yield stress of the material of the stiffener, in N/mm^2

$\sigma_{yd\text{-}plt}$ = specified minimum yield stress of the material of the attached plate, in N/mm^2

σ_{hg} = maximum hull girder stress of sagging and hogging, in N/mm^2, as defined in Table 3.2.5 and Table 3.4.3 in Chapter 3, for stiffeners in cargo tank region and machinery spaces respectively and not to be taken as less than $0,4\sigma_{yd\text{-}plt}$

Z_{net} = net section modulus, in way of face-plate/free edge of the stiffener, in cm^3

$Z_{net\text{-}plt}$ = net section modulus, in way of the attached plate of stiffener, in cm^3.

8.3 Effective shear span

8.3.1 The effective shear span of a stiffener may be reduced due to the presence of brackets, provided the brackets are effectively supported by the adjacent structure, otherwise the effective shear span is to be as the full length, as given in 8.3.3.

8.3.2 The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener. If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to that of the stiffener, the effective shear span may be calculated using the longer effective bracket arm.

8.3.3 The effective shear span may be reduced by a minimum of s/4000 m at each end of the member, regardless of support detail, hence the effective shear span is not to be taken greater than:

$$l_{shr} \leq l - \frac{s}{2000} \quad \text{m}$$

where

l = full length of the stiffener between primary support members, in metres

s = stiffener spacing, in mm.

8.4 Effective elastic sectional properties of local support members

8.4.1 The net elastic shear area of local support members is to be taken as:

$$A_{shr-el-net} = \frac{(h_{stf} + t_{p-net})\, t_{w-net} \sin \varphi_w}{100} \quad \text{cm}^2$$

where

h_{stf} = stiffener height, including face-plate, in mm

$t_{p\text{-}net}$ = net thickness of attached plate, in mm

$t_{w\text{-}net}$ = net web thickness, in mm

φ_w = angle between the stiffener web and attached plating, in degrees. φ_w is to be taken as 90° if the angle is greater than or equal to 75°.

8.4.2 The effective shear depth of stiffeners is to be taken as:

$$d_{shr} = (h_{stf} + t_{p-net}) \sin \varphi_w \quad \text{mm}$$

where

h_{stf}, $t_{p\text{-}net}$, φ_w are defined in 8.4.1.

8.4.3 The elastic net section modulus of local support members is to be taken as:

$$Z_{el-\varphi-net} = Z_{stf-net} \sin \varphi_w \quad \text{cm}^3$$

where

$Z_{stf\text{-}net}$ = net section modulus of corresponding upright stiffener, i.e., when φ_w is equal to 90°, in cm^3

φ_w is defined in 8.4.1.

8.5 Effective plastic section modulus and shear area of stiffeners

8.5.1 The net plastic shear area of local support members is to be taken as:

$$A_{shr-pl-net} = \frac{(h_{stf} + t_{p-net})\, t_{w-net} \sin \varphi_w}{100} \text{ cm}^2$$

where

h_{stf}, t_{p-net}, φ_w are defined in 8.4.1

t_{w-net} = net web thickness, in mm.

8.5.2 The effective net plastic section modulus of local support members is to be taken as:

$$Z_{pl-net} = \frac{f_w\, d_w^2\, t_{w-net} \sin \varphi_w}{2000} + \frac{(2\gamma - 1)\, A_{f-net}\, (h_{f-ctr} \sin \varphi_w - b_{f-ctr} \cos \varphi_w)}{1000} \text{ cm}^3$$

where

f_w = web shear stress factor
= 0,75 for flanged profile cross-sections with n = 1 or 2
= 1,0 for flanged profile cross-sections with n = 0 and for flat bar stiffeners

n = number of moment effective end supports of each member
= 0, 1 or 2

A moment effective end support may be considered where:

(a) the stiffener is continuous at the support;

(b) the stiffener passes through the support plate while it is connected at its termination point by a carling (or equivalent) to adjacent stiffeners;

(c) the stiffener is attached to an abutting stiffener effective in bending (not a buckling stiffener) or bracket. The bracket is assumed to be bending effective when it is attached to another stiffener (not a buckling stiffener).

d_w = depth of stiffener web, in mm:
= $h_{stf-tf-net}$ for T, L (rolled and built-up) and L2 profiles
= h_{stf} for flat bar and L3 profiles to be taken as given in Table 1.8.1 and Table 1.8.2 for bulb profiles

γ = $0,25\,(1 + \sqrt{3 + 12\beta}\,)$

β = 0,5 for all cases, except L profiles without a mid span tripping bracket
= $\dfrac{10^6\, t_{w-net}^2\, f_b\, l_f^2}{80 b_f^2\, t_{f-net}\, h_{f-ctr}} + \dfrac{t_{w-net}}{2 b_f}$

but not to be taken greater than 0,5 for L (rolled and built-up) profiles without a mid span tripping bracket

A_{f-net} = net cross-sectional area of flange, in mm²
= $b_f\, t_{f-net}$ in general
= 0 for flat bar stiffeners

b_f = breadth of flange, in mm. For bulb profiles, *see* Table 1.8.1 and Table 1.8.2

b_{f-ctr} = distance from mid thickness of stiffener web to the centre of the flange area:
= $0,5\,(b_f - t_{w-grs})$ for rolled angle profiles
= 0 for T profiles
as given in Table 1.8.1 and Table 1.8.2 for bulb profiles

h_{f-ctr} = height of stiffener measured to the mid thickness of the flange:
= $h_{stf} - 0,5 t_{f-net}$ for profiles with flange of rectangular shape except for L3 profiles

Table 1.8.1 Characteristic flange data for HP bulb profiles (*see* Fig. 1.8.1)

h_{stf} (mm)	d_w (mm)	b_{f-grs}* (mm)	t_{f-grs}* (mm)	b_{f-ctr} (mm)	h_{f-ctr} (mm)
200	171	40	14,4	10,9	188
220	188	44	16,2	12,1	206
240	205	49	17,7	13,3	225
260	221	53	19,5	14,5	244
280	238	57	21,3	15,8	263
300	255	62	22,8	16,9	281
320	271	65	25,0	18,1	300
340	288	70	26,4	19,3	318
370	313	77	28,8	21,1	346
400	338	83	31,5	22,0	374
430	363	90	33,9	24,7	402

NOTE

Characteristic flange data converted to net scantlings are given as:

$b_f = b_{f-grs}{}^* + 2t_{w-net}$

$t_{f-net} = t_{f-grs}{}^* - t_c$

$t_{w-net} = t_{wgrs} - t_c$

Table 1.8.2 Characteristic flange data for JIS bulb profiles (*see* Fig. 1.8.1)

h_{stf} (mm)	d_w (mm)	$b_{f\text{-}grs}$ * (mm)	$t_{f\text{-}grs}$ * (mm)	$b_{f\text{-}ctr}$ (mm)	$h_{f\text{-}ctr}$ (mm)
180	156	34	11,9	9,0	170
200	172	39	13,7	10,4	188
230	198	45	15,2	11,7	217
250	215	49	17,1	12,9	235

NOTE
Characteristic flange data converted to net scantlings are as given in Table 1.8.1.

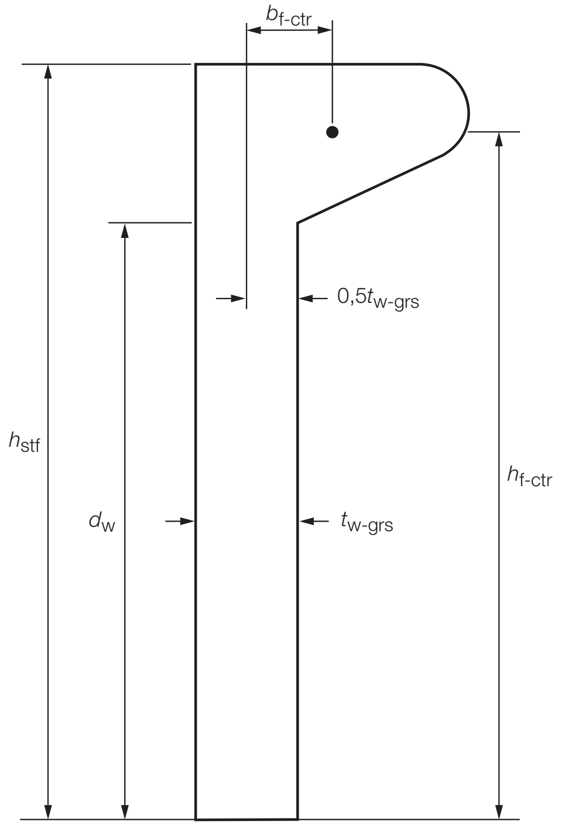


Fig. 1.8.1 Characteristic data for bulb profiles

= $h_{stf} - d_{edge} - 0,5t_{f\text{-}net}$ for L3 profiles
as given in Table 1.8.1 and Table 1.8.2 for bulb profiles

d_{edge} distance from upper edge of web to the top of the flange, in mm

f_b = 1,0 in general
= 0,8 for continuous flanges with end bracket(s). A continuous flange is defined as a flange that is not sniped and continuous through the primary support member
= 0,7 for non-continuous flanges with end bracket(s). A non-continuous flange is defined as a flange that is sniped at the primary support member or terminated at the support without aligned structure on the other side of the support

l_f = length of stiffener flange between supporting webs, in metres, but reduced by the arm length of end bracket(s) for stiffeners with end bracket(s) fitted

$t_{f\text{-}net}$ = net flange thickness, in mm
= 0 for flat bar stiffeners
as given in Table 1.8.1 and Table 1.8.2 for bulb profiles

$t_{w\text{-}net}$, h_{stf}, φ_w are defined in 8.4.1.

■ *Section 9* Mooring structure

9.1 General

9.1.1 General requirements for turret mooring structures are given in Pt 3, Ch 13,3.

9.1.2 General requirements for mooring arm structures are given in Pt 3, Ch 13,4.

9.1.3 The minimum hull modulus in way of turret areas and other large openings is to satisfy the Rule requirements for longitudinal strength. When the turret is situated within 0,5L amidships, the minimum hull midship section modulus about the transverse neutral axis at deck or keel is to be maintained in way of the turret opening. Increases in plate thicknesses are to take place gradually. Any reduction in hull section modulus should be kept to a minimum and compensation fitted where necessary.

9.1.4 For a turret-moored unit with a turret well opening, suitable precautions are to be taken to prevent damage to the well structure in transit and when disconnected, when applicable.

9.1.5 The hull structure in way of mooring connections is to be verified by direct calculation. In all cases, the structural analysis is to include a representative portion of the hull and tank structure, together with the integration of the mooring system with the unit's structure. The analysis is to be in accordance with the LR ShipRight Procedure for Ship Units and Pt 4, Ch 5, as applicable.

9.1.6 Continuity of primary structural elements is to be maintained as far as practicable in way of turret openings and mooring support structure.

9.1.7 Turret bearings are to comply with Pt 3, Ch 2. The turret bearing support structure is to be integrated into the hull structure.

■ *Section 10*
Topside structure

10.1 General

10.1.1 The minimum scantlings of superstructures and deck-houses are to comply with the requirements of Pt 3, Ch 8 of the Rules for Ships. Bulwarks and guard-rails are to comply with Pt 4, Ch 6,10 but special consideration is to be given to the scantlings of bulwarks at the fore end or screens protecting the swivel stack. In general, the scantlings of bulwarks at the fore end are not to be less than required for deck-house fronts at the position under consideration.

10.1.2 For units with unconventional forward ends and units which may be subjected to high deck loading in excess of the minimum Rule heads due to loading from green seas, adequate protection by means of bulwarks and breakwater structure is to be provided at the forward end and the scantlings of the structure and its under-deck supports are to be specially considered. Where necessary the loadings are to be determined by model tests.

10.1.3 The boundary bulkheads of accommodation spaces which may be subjected to blast loading in accordance with Pt 7, Ch 3 are to be designed in accordance with Pt 4, Ch 3,4 and permissible stress levels are to satisfy the factors of safety given in Pt 4, Ch 5,2.1.1(c).

10.1.4 For units fitted with a process plant facility and/or drilling equipment, the support stools and integrated hull support structure to the process plant and other equipment-supporting structures, including derricks and flare structures, are considered to be classification items, regardless of whether or not the process/drilling plant facility is classed, and the loadings are to be determined in accordance with Pt 3, Ch 8,2. Loading from the topsides should consider the most onerous scenarios, including environmental loads, equipment operating weights and inertia loads due to hull motions. Permissible stress levels are to comply with Pt 4, Ch 5 or Chapter 3.

10.1.5 Equipment supports are to take into account hull deflections when considered necessary.

■ *Section 11*
Green water and wave impact

11.1 General

11.1.1 Green water is taken to mean the overtopping by water in severe wave conditions, resulting in loading on the deck structure and any exposed equipment. Significant amounts of green water will have an impact on the vessel deck structural design, accommodation superstructure, equipment design and layout and may induce vibrations in the hull. The effects of green water loading should be accounted for, where applicable.

11.1.2 The requirements of Ch 2,3.8, Ch 2,7.4 and Ch 3,6 are to be complied with, *see also* Section 5 and Section 6.

11.1.3 Appropriate measures should be considered to minimise green water effects on the structure and critical equipment, including bow shape design, flare, breakwaters and other protective structure such as turret housings. Adequate drainage arrangements must also be provided, *see also* Pt 4, Ch 7,10.

11.1.4 Wave slamming effects should be taken into account for both hull and mooring structure design. Locations on the hull which may be subject to effects of wave impact include the forward bottom structure, stern structure, bow flare and bow side. The effects of slamming on the structure should be considered in design, particularly with regard to enhancement of global hull girder bending moments and shear loadings induced, local strength aspects and limitations to ballast draft conditions.

11.1.5 It is recommended that provisions are made during model testing, for measurement of both green water loading and wave slamming pressures which can be used for local structural design.

■ *Section 12*
Corrosion additions

12.1 General

12.1.1 The net scantling approach is described in 12.2. Corrosion additions are defined in 12.3 and in-operation steel renewal criteria are defined in Section 13.

12.1.2 The requirements for corrosion protection given in Part 8 are to be complied with.

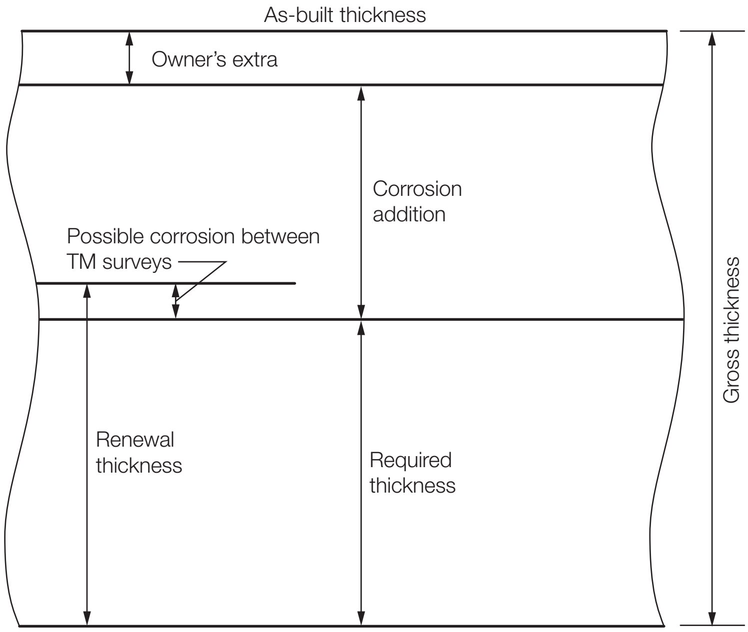


Fig. 1.12.1 Net scantling approach

12.2 Net scantling approach

12.2.1 The net thickness of a structural element is that required for structural strength compliance with the design basis. The corrosion addition for structural elements is derived independently of the net scantling requirements. This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the in-operation phase. This approach enables the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the unit. *See* Fig. 1.12.1.

12.2.2 The net thickness approach distinguishes between local and global corrosion. Local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener. Global corrosion is defined as the overall average corrosion of larger areas such as primary support members and the hull girder.

12.3 Corrosion additions

12.3.1 The corrosion additions specified in this sub-Section are applicable to each of the two sides of a structural member and are given as a corrosion rate. The corrosion rate for each of the two sides of a structural member is specified in Table 1.12.1. However, consideration will be given to alternative corrosion rates if these are contractually agreed between the Owner and Shipyard.

12.3.2 The total corrosion addition for a structural member is given by the following formula:

$t_c = N_c\,(t_{c1} + t_{c2})$ mm, rounded up to the nearest 0,5 mm

where

N_c = number of years of unit life where coating is not fully effective, see Fig. 1.12.3. N_c is not to be less than 10 years for new-builds and not less than 5 years for conversions and redeployments. Where cargo tanks remain uncoated, N_c is to be taken as equal to the unit design life

t_{c1}, t_{c2} = corrosion rate for each side of the structural member, as given in Table 1.12.1

For example calculations of corrosion additions, *see* Fig. 1.12.2.

12.3.3 The corrosion rates for cargo and ballast water tanks given in Table 1.12.1 assume the tanks will spend 50 per cent of the time empty and 50 per cent of the time full over the unit design life and that the ballast tank is fitted with effective anodes. Where alternative regimes for individual tanks are specified, the corrosion rate may be adjusted by [percentage time empty/50] x corrosion rate from Table 1.12.1. The percentage time empty is not to be taken as less than 25 per cent.

12.3.4 The default coating life is to be taken as 15 years. Alternative corrosion additions may be derived using the general principles shown in Fig. 1.12.3 where an alternative coating life is specified.

Table 1.12.1 Corrosion rate for one side of structural member

Compartment type	Structural member	Corrosion rate t_{c1}, t_{c2} (mm/year)
Ballast water tank	Within 3 m below top tank, *see* Note 1 Elsewhere	0,15 0,1
Cargo oil tank	Within 3 m below top of tank, *see* Note 1 Bottom of single bottom tanks Elsewhere	0,125 0,125 0,075
Exposed to atmosphere	Weather deck plating Other members	0,1 0,075
Exposed to sea-water	Shell plating	0,075
Fuel and lubricating oil tank, *see* Note 3		0,05
Fresh water tank		0,05
Slop tanks		0,15
Void spaces, *see* Note 2	Spaces not normally accessed, e.g., access only via bolted manhole openings, pipe tunnels, inner surface of stool space common with a dry bulk cargo hold, etc.	0,05
	Chocks and supports for independent tanks located in a void space	
Dry spaces	Internals of machinery spaces, pump-room, store rooms, steering gear space, etc.	0,05

NOTES
1. This is only applicable to cargo tanks and ballast tanks with weather deck as the tank top.
2. The corrosion rate on the outer shell plating in way of a pipe tunnel is to be taken as for a water ballast tank.
3. 0,07 mm/year is to be added to the plate surface exposed to ballast for the plate boundary between water ballast and heated cargo oil tanks. 0,03 mm/year is to be added to each surface of the web and face plate of a stiffener in a ballast tank and attached to the boundary between water ballast and heated cargo oil tanks. Heated cargo oil tanks are defined as tanks arranged with any form of heating capability.

12.3.5 To address the risk of pitting corrosion, the gross thickness of the bottom plating of tanks is not to be less than:

$$t_{grs} = 6 + N_t (20t_{c1} + t_{c2})$$

where

N_t = number of years between surveys (not to be taken as less than 5 for new builds or 2,5 for conversions)

t_{c1} and t_{c2} are defined in 12.3.2. t_{c1} is the value for the side of the structural member within the tank.

Explanatory note:
This requirement ensures that there is sufficient bottom plating thickness remaining at thickness measurement survey so that pitting corrosion should not lead to loss of barrier integrity between inspections.

12.4 Scantling compliance

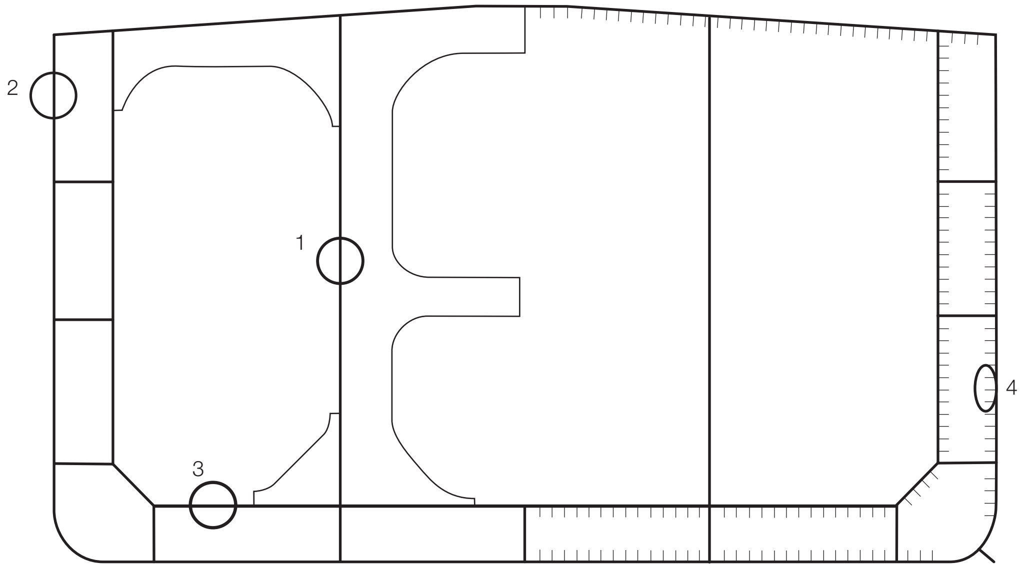
12.4.1 The minimum net thicknesses of structural items as required by Chapter 3 are to be rounded to the nearest 0,5 mm prior to the addition of Owner's extras or corrosion additions. The applicable corrosion additions are given in 12.3.

12.4.2 The net section modulus, moment of inertia and shear area properties of local support members are to be calculated using the net thicknesses of the attached plate, web and flange.

12.4.3 The net section properties, shear area and section modulus of primary support members are to be calculated using the net thicknesses of the attached plate, web and flange plus half of the applicable corrosion addition specified in 12.3.

12.4.4 The net scantlings described in this sub-Section are related to gross scantlings as follows:

(a) for application of the minimum thickness requirements, the gross thickness is obtained from the applicable requirements by adding the full corrosion additions specified in 12.3;
(b) for plating and local support members, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in 12.3;
(c) for primary support members, the gross shear area, gross section modulus and other gross cross-sectional properties are obtained from the applicable requirements by adding one half of the relevant full corrosion additions specified in 12.3;



1 **Longitudinal bulkhead plating**
Corrosion addition (Table 1.12.1) = 0,075 mm/year for each side of the plating
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,075 + 0,075) = 10 x 0,15 = 1,5 mm

2 **Side shell plating (within 3 m below top of tank)**
Corrosion addition (Table 1.12.1) = 0,075 mm/year for side shell plating
Corrosion addition (Table 1.12.1) = 0,15 mm/year for ballast water tank
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,075 + 0,15) = 10 x 0,225 = 2,25 mm = 2,5 mm rounded

3 **Cargo tank bottom plating**
Corrosion addition (Table 1.12.1) = 0,075 mm/year for cargo tank plating
Corrosion addition (Table 1.12.1) = 0,1 mm/year for ballast water tank
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,075 + 0,1) = 10 x 0,175 = 1,75 mm = 2 mm rounded

4 **Stiffeners in ballast water tank**
Corrosion addition (Table 1.12.1) = 0,1 mm/year for each side in ballast water tank
Unit design life = 25 years
Effective coating life = 15 years
Total corrosion addition = (25 – 15) x (0,1 + 0,1) = 10 x 0,2 = 2 mm

NOTE
This example assumes that the tanks will spend 50 per cent of the time empty and 50 per cent of the time full over the unit design life.

Fig. 1.12.2 Example calculations of corrosion additions

(d) for application of buckling requirements, the gross thickness and gross cross-sectional properties are obtained from the applicable requirements by adding the full corrosion additions specified in 12.3.

12.4.5 Any additional thickness specified by the Owner as Owner's extra margin is not to be included when considering compliance with this Section.

12.4.6 For the subject analysis types, the corrosion applied to the gross scantlings prior to the compliance assessment is given in Table 1.12.2.

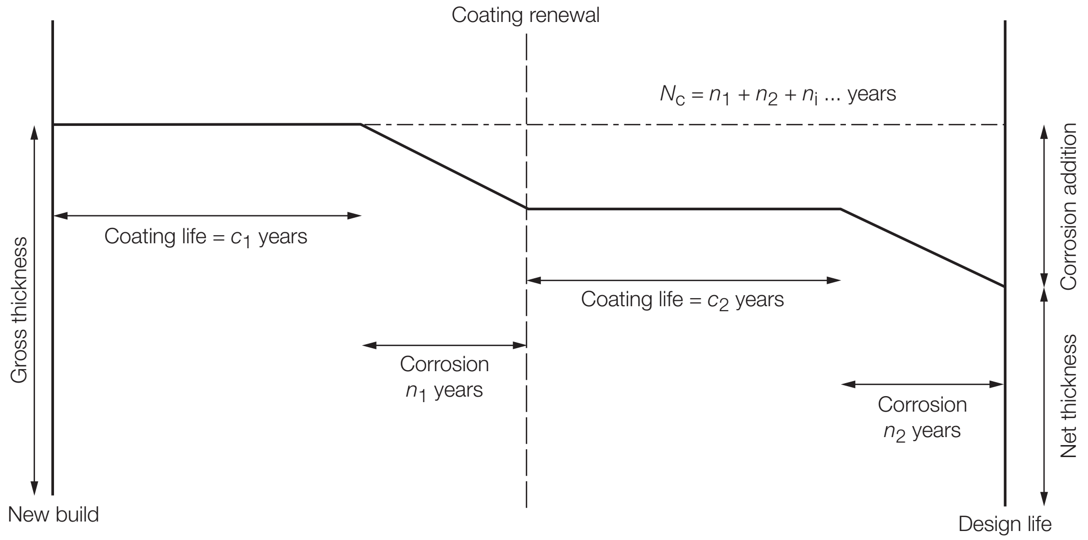


Fig. 1.12.3 Generic example unit life cycle

Table 1.12.2 Corrosion applied to the gross scantling for assessment

Assessment		Stress calculations	Buckling capacity calculations
Minimum thickness	Thickness	t_c	N/A
Local strength (plates, stiffeners, and hold frames)	Thickness/sectional properties Stiffness/proportions	t_c t_c	N/A t_c
Primary support members (Prescriptive)	Thickness/sectional properties Stiffness/proportions of web and flange	$0,5t_c$ t_c	N/A t_c
Strength	Global coarse mesh Local fine mesh	$0,5t_c$ t_c	t_c
Fatigue	Global coarse mesh Local fine mesh	$0,25t_c$ $0,5t_c$	N/A
Sloshing	Sloshing	t_c	t_c
Fracture	Global coarse mesh Local extremely fine mesh	$0,25t_c$ $0,5t_c$	N/A
Ultimate strength	Ultimate strength	$0,5t_c$	$0,5t_c$

NOTES
For the assessment, the gross scantling used is not to include any Owner's extra.

Section 13
Steel renewal criteria

13.1 General

13.1.1 The plans to be supplied on board the ship unit, *see* 2.3, are to include both the as-built and renewal thicknesses. Any Owner's extra thickness is also to be clearly indicated on the drawings. The as-built Midship Section plan provided by the Builder and carried on board the ship unit is to include a Table showing the minimum allowable hull girder sectional properties for the mid-tank transverse section in all cargo tanks.

13.1.2 Re-examination and additional thickness measurements are required annually where the coating condition is POOR, as defined in Pt 1, Ch 3,1.5.12.

13.1.3 Steel renewal is to be carried out when the measured thickness is less than:

$t = t_{net} + N_t (t_{c1} + t_{c2})$ mm, rounded up to the nearest 0,25 mm

For tank bottom plating:

$t = 6 + N_t (20t_{c1} + t_{c2})$ mm, rounded up to the nearest 0,25 mm

where

t_{net} = required net thickness
N_t = number of years between surveys (not to be taken as greater than 5 years or less than 1 year)
t_{c1} and t_{c2} are defined in 12.3.2.

13.2 Definitions

13.2.1 General corrosion is defined as areas where general uniform reduction of material thickness is found over an extensive area.

13.2.2 Pitting corrosion is defined as scattered corrosion spots/areas with local material reductions which are greater than the general corrosion in the surrounding area. The pitting intensity is defined in Fig. 1.13.1.

13.2.3 Edge corrosion is defined as local corrosion at the free edges of plates, stiffeners, primary support members and around openings. An example of edge corrosion is shown in Fig. 1.13.2.

13.2.4 Groove corrosion is typically local material loss adjacent to weld joints along abutting stiffeners and at stiffener or plate butts or seams. An example of groove corrosion is shown in Fig. 1.13.3.

13.3 Local structure

13.3.1 For local structure when general corrosion has occurred, steel renewal is required where the measured thickness is less than the renewal thickness:

$t = t_{net} + t_{c1} + t_{c2}$ mm, rounded up to the nearest 0,25 mm

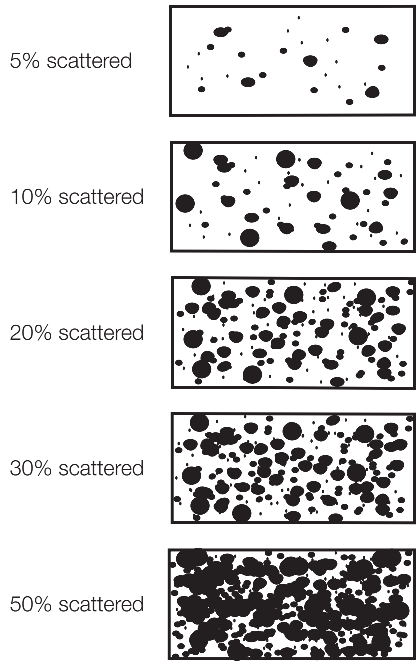


Fig. 1.13.1 Pitting intensity

where

t_{net} = required net thickness
t_{c1} and t_{c2} are defined in 12.3.2.

For inspection intervals greater than one year, this criterion assumes that a localised reduction in the net thickness can be tolerated.

13.3.2 For plates with pitting intensity less than 20 per cent, *see* Fig. 1.13.1, steel renewal is required where the measured thickness of any one measurement is less than:

0,7 (as-built thickness – Owner's extra); or
1 mm less than the renewal thickness.

For all levels of pitting intensity, steel renewal is also required where the average thickness across any cross-section in the plating is less than the renewal criteria for general corrosion given in 13.3.1.

13.3.3 Where the overall height or breadth of edge corrosion is less than 25 per cent of the stiffener height or flange breadth, h_{stf} or b_{stf} in Fig. 1.13.2, steel renewal is required where the measured thickness is less than:

0,7 (as-built thickness – Owner's extra); or
1 mm less than the renewal thickness.

Steel renewal is also required where the average thickness across the breadth or height of the stiffener is less than the renewal criteria for general corrosion given in 13.3.1.

Where edge corrosion extends over more than 25 per cent of the height or breadth of the stiffener, local renewal criteria for general corrosion as defined in 13.3.1 is to be used.

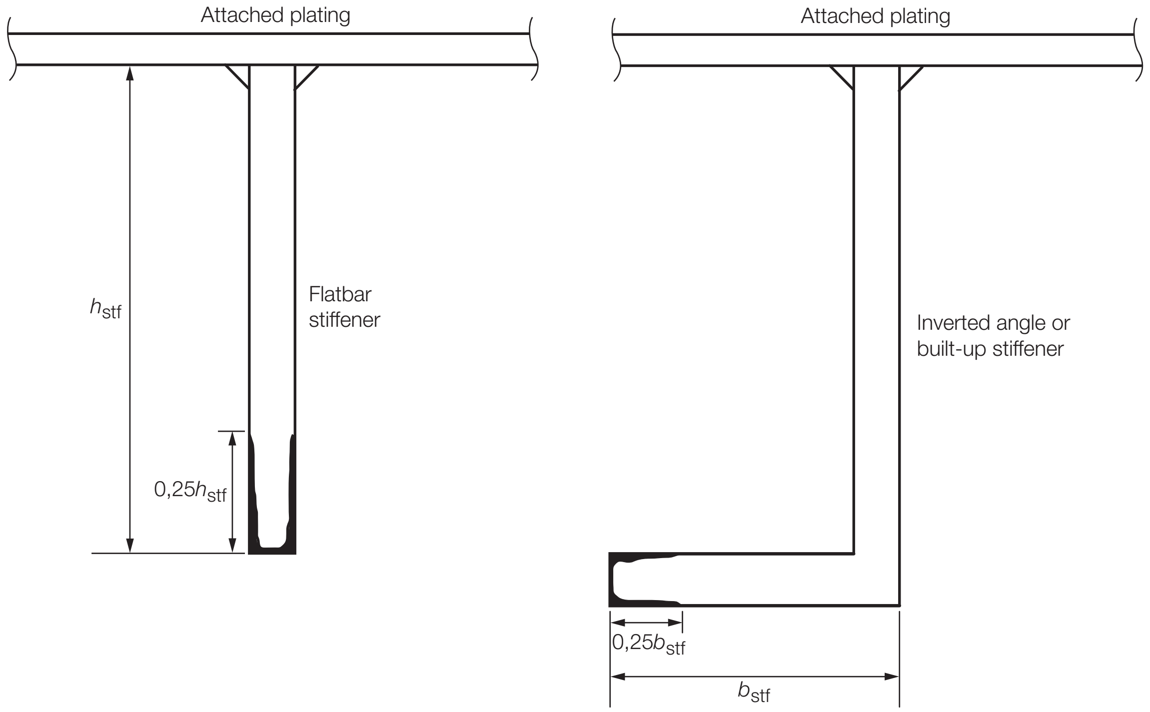


Fig. 1.13.2 Edge corrosion

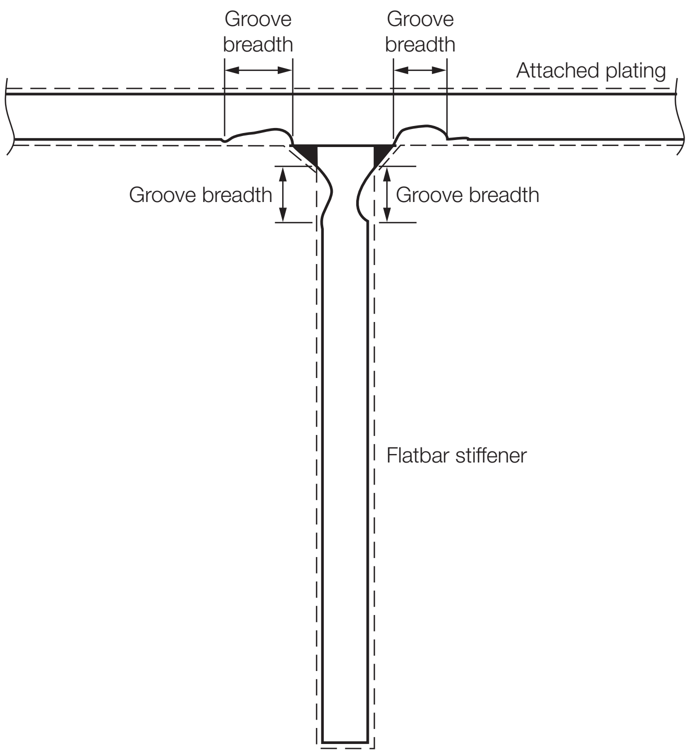


Fig. 1.13.3 Groove corrosion

13.3.4 Plate edges at openings for manholes, lightening holes, etc., may be below the minimum thickness given in 13.3.1, provided that:

(a) the maximum extent of the reduced plate thickness, below the minimum given in 13.3.1, from the opening edge is not more than 20 per cent of the smallest dimension of the opening and does not exceed 100 mm;
(b) rough or uneven edges may be cropped back, provided that the maximum dimension of the opening is not increased by more than 10 per cent.

13.3.5 For grooved areas, steel renewal is required where the measured thickness is less than:

0,75 (as-built thickness – Owner's extra);
0,5 mm less than the renewal thickness; or
less than 6 mm.

Members with areas of grooving greater than 15 per cent of the web height or 30 mm are to be assessed based on the criteria for general corrosion as defined in 13.3.1, using the average measured thickness across the plating/stiffener.

13.4 Hull girder section

13.4.1 The following actual hull girder sectional properties are required to be verified:

(a) vertical hull girder moment of inertia, about the horizontal axis;
(b) hull girder section modulus about the horizontal axis – at deck-at-side;
(c) hull girder section modulus about the horizontal axis – at keel;
(d) hull girder section modulus about the vertical axis – at side;
(e) hull girder vertical shear area.

13.4.2 The minimum allowable hull girder section properties are to be calculated with every member at a thickness equal to its required net minimum thickness plus half the applicable corrosion addition given in 12.3.

■ *Section 14* Local strength and structural details

14.1 General

14.1.1 Design for local strength of walkways, decks loaded by wheeled vehicles, helicopter landing areas, guard rails, bulwarks and other means for the protection of crew and other personnel is to comply with the requirements of Pt 4, Ch 6.

14.1.2 Watertight and weathertight integrity and load lines are to comply with the requirements of Pt 4, Ch 7, as applicable.

14.1.3 Welding, NDE, connections, structural details and fabrication tolerances are to comply with the requirements of Pt 4, Ch 8, as applicable.

14.1.4 Anchoring and towing equipment are to comply with the requirements of Pt 4, Ch 9, as applicable.

14.1.5 Steering arrangements are to comply with the requirements of Pt 4, Ch 10, as applicable.

14.1.6 Requirements additional to these Rules may be imposed by the National Administration in the area of operation and/or the country of administration, as applicable.

■ *Section 15* In-service assessment

15.1 General

15.1.1 Any damage, defect, etc., is to be reported to LR without delay, *see* Pt 1, Ch 2,1.1.7.

15.1.2 All repairs and other measures are to be agreed with LR, *see* Pt 1, Ch 2,3.4.

15.1.3 Details of an acceptable procedure for the assessment of structural defects in service are outlined in the LR ShipRight Procedure for Ship Units.

■ *Section 16* Sloshing

16.1 General

16.1.1 When the partial filling of tanks is contemplated in operating conditions, the sloshing loads on tank boundaries are to be assessed in accordance with the LR ShipRight Procedure for Ship Units. Full account is to be taken of the operating requirements on station with regard to the filling, transfer and export operations for cargo bulk storage tanks.

■ *Section 17* Hull girder ultimate strength

17.1 General

17.1.1 The hull girder ultimate strength is to be assessed in accordance with the LR ShipRight Procedure for Ship Units.

Section 18
Buckling

18.1 General

18.1.1 **Symbols**. The symbols used in this Chapter are defined as follows:

η_{allow} = allowable buckling utilisation factor, as defined in Ch 3,1.5.2
σ_x, σ_y = actual compressive stresses for plates, in N/mm^2
σ_x = compressive axial stress in the stiffener, in N/mm^2, in way of the midspan of the stiffener
τ = actual shear stress, in N/mm^2
σ_{xcr}, σ_{ycr} = critical compressive stress, in N/mm^2, as defined in 18.2.1.3
τ_{cr} = critical shear stress, in N/mm^2, as defined in 18.2.1.3
K = buckling factor, *see* Table 1.18.1
σ_E = reference stress, in N/mm^2
$= 0{,}9E\left(\dfrac{t_{net}}{l_a}\right)^2$
E = modulus of elasticity, 206 000 N/mm^2
t_{net} = net thickness of plate panel, in mm
l_a = length of the side of the plate panel, as defined in Table 1.18.1, in mm
σ_{yd} = specified minimum yield stress of the material, in N/mm^2
C_x, C_y, C_τ = reduction factors, as given in Table 1.18.1
σ_b = bending stress at the midspan of the stiffener according to 18.3.2.3, in N/mm^2
s = stiffener spacing, in mm
d_w = depth of web plate, in mm, as shown in Fig. 1.18.1
$t_{f\text{-}net}$ = net flange thickness, in mm
$t_{w\text{-}net}$ = net web thickness, in mm
b_f = flange breadth, in mm
ν = Poisson's ratio, 0,3.

18.1.2 **Scope**

18.1.2.1 This Section contains the methods for determination of the buckling capacity, definitions of buckling utilisation factors and other measures necessary to control buckling of plate panels, stiffeners and primary support members.

18.1.2.2 The buckling utilisation factor is to satisfy the following criteria:

$$\eta \le \eta_{allow}$$

18.1.2.3 For structural idealisation and definitions *see also* Section 8. The thickness and section properties of plates and stiffeners are to be taken as specified by the appropriate Rule requirements.

18.2 Buckling of plates

18.2.1 **Uni-axial buckling of plates**.

18.2.1.1 The buckling utilisation factor for uni-axial stress is to be taken as:

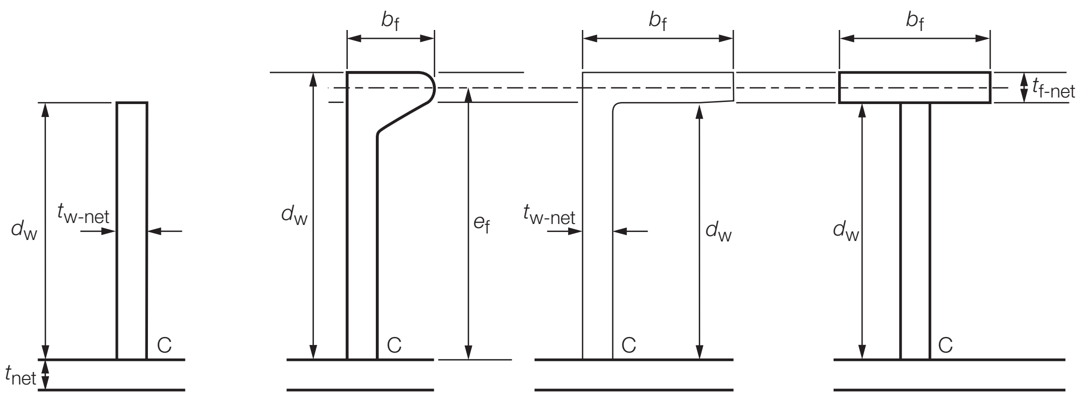
$$\eta = \frac{\sigma_x}{\sigma_{xcr}} \text{ for compressive stresses in x-direction}$$

$$\eta = \frac{\sigma_y}{\sigma_{ycr}} \text{ for compressive stresses in y-direction}$$

$$\eta = \frac{\tau}{\tau_{cr}} \text{ for shear stress.}$$

18.2.1.2 Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{\sigma_{yd}}{K\,\sigma_E}}$$



NOTE
Measurements of breadth and depth are based on gross scantlings

Fig. 1.18.1 Stiffener cross-sections

Table 1.18.1 Buckling factor and reduction factor for plane plate panels (*see continuation*)

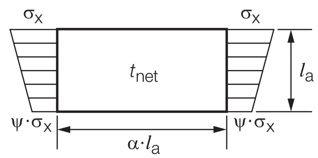
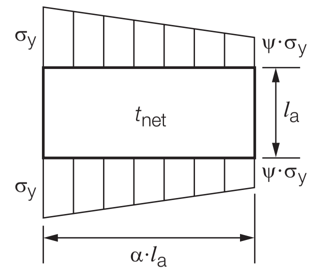
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
1 	$1 \geq \psi \geq 0$	$\alpha > 1$	$K = \dfrac{8,4}{\psi + 1,1}$	$C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c\left(\dfrac{1}{\lambda} - \dfrac{0,22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ where $c = (1,25 - 0,12\psi) \leq 1,25$ $\lambda_c = \dfrac{c}{2}\left(1 + \sqrt{1 - \dfrac{0,88}{c}}\right)$
	$0 > \psi > -1$		$K = 7,63 - \psi\,(6,26 - 10\psi)$	
	$\psi \leq -1$		$K = 5,975\,(1 - \psi)^2$	
2 	$1 \geq \psi \geq 0$	$\alpha \geq 1$	$K = \left(1 + \dfrac{1}{\alpha^2}\right)^2 \dfrac{2,1}{(\psi + 1,1)}$	$C_y = c\left(\dfrac{1}{\lambda} - \dfrac{R + F^2\,(H - R)}{\lambda^2}\right)$ where $c = (1,25 - 0,12\psi) \leq 1,25$ $R = \lambda\,(1 - \lambda/c)$ for $\lambda < \lambda_c$ $R = 0,22$ for $\lambda \geq \lambda_c$ $\lambda_c = 0,5c\left(1 + \sqrt{1 - 0,88/c}\right)$ $F = \left(1 - \left(\dfrac{K}{0,91} - 1\right) / \lambda_p^2\right) c_1 \geq 0$ $\lambda_p^2 = \lambda^2 - 0,5$ and $1 \leq \lambda_p^2 \leq 3$ $c_1 = 1$ for σ_y due to direct loads (3) $c_1 = (1 - 1/\alpha) \geq 0$ for σ_y due to bending (in general) (2) $c_1 = 0$ for σ due to bending in extreme load cases (e.g., w/t.bhds.) $H = \lambda - \dfrac{2\lambda}{c\,(T + \sqrt{T^2 - 4})} \geq R$ $T = \lambda + \dfrac{14}{15\lambda} + \dfrac{1}{3}$
	$0 > \psi > -1$	$1 \leq \alpha \leq 1,5$	$K = \left[1 + \dfrac{1}{\alpha^2}\right]^2 \dfrac{2,1\,(1 + \psi)}{1,1} - \dfrac{\psi}{\alpha^2}\,(13,9 - 10\psi)$	
		$\alpha > 1,5$	$K = \left[1 + \dfrac{1}{\alpha^2}\right]^2 \dfrac{2,1\,(1 + \psi)}{1,1} - \dfrac{\psi}{\alpha^2}\,(5,87 + 1,87\alpha^2 + \dfrac{8,6}{\alpha^2} - 10\psi)$	
	$\psi \leq -1$	$1 \leq \alpha \leq \dfrac{3\,(1 - \psi)}{4}$	$K = \left(\dfrac{1 - \psi}{\alpha}\right)^2 5,975$	
		$\alpha > \dfrac{3\,(1 - \psi)}{4}$	$K = \left(\dfrac{1 - \psi}{\alpha}\right)^2 3,9675 + 0,5375\left(\dfrac{1 - \psi}{\alpha}\right)^4 + 1,87$	

Table 1.18.1 Buckling factor and reduction factor for plane plate panels (*continued*)

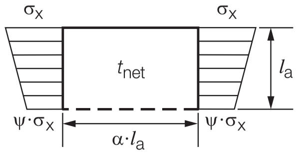
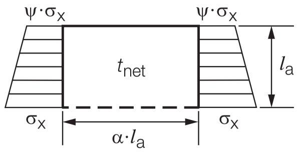
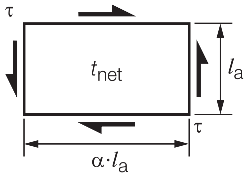
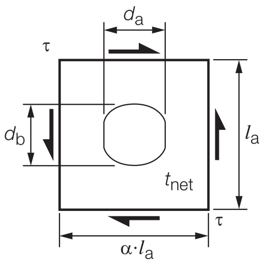
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
3 	$1 \geq \psi \geq 0$	$\alpha > 0$	$K = \dfrac{4\,(0{,}425 + 1/\alpha^2)}{3\psi + 1}$	$C_x = 1$ for $\lambda \leq 0{,}7$ $C_x = \dfrac{1}{\lambda^2 + 0{,}51}$ for $\lambda > 0{,}7$
	$0 > \psi \geq -1$		$K = 4\,(0{,}425 + 1/\alpha^2)\,(1 + \psi) - 5\psi\,(1 - 3{,}42\psi)$	
4 	$1 \geq \psi \geq -1$	$\alpha > 0$	$K = \left(0{,}425 + \dfrac{1}{\alpha^2}\right)\dfrac{3 - \psi}{2}$	
5 			$K = K_\tau \sqrt{3}$	$C_\tau = 1$ for $\lambda \leq 0{,}84$ $C_\tau = \dfrac{0{,}84}{\lambda}$ for $\lambda > 0{,}84$
		$\alpha \geq 1$	$K_\tau = \left[5{,}34 + \dfrac{4}{\alpha^2}\right]$	
		$0 < \alpha < 1$	$K_\tau = \left[4 + \dfrac{5{,}34}{\alpha^2}\right]$	
6 			$K = K' r$ $K' = K$ according to Case 5 r = opening red. factor $r = \left(1 - \dfrac{d_a}{\alpha\, l_a}\right)\left(1 - \dfrac{d_b}{l_a}\right)$ $\dfrac{d_a}{\alpha\, l_a} \leq 0{,}7$ and $\dfrac{d_b}{l_a} \leq 0{,}7$	

Table 1.18.1 Buckling factor and reduction factor for plane plate panels *(conclusion)*

where ψ = the ratio between smallest and largest compressive stress, as shown for Cases 1 to 4 l_a = length, in mm, of the shorter side of the plate panel for Cases 1 and 2 l_a = length, in mm, of the side of the plate panel, as defined for Cases 3, 4, 5 and 6 α = aspect ratio of the plate panel
Edge boundary conditions: - - - - - - - - plate edge free ——— plate edge simply supported
NOTES 1. Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates. 2. c_1 due to bending (in general) corresponds to straight edges (uniform displacement) of a plate panel integrated in a large structure. This value is to be applied for hull girder buckling and buckling of web plate of primary support members in way of openings. 3. c_1 for direct loads corresponds to a plate panel with edges not restrained from pull-in which may result in non-straight edges.

18.2.1.3 The critical stresses, σ_{xcr}, σ_{ycr} or τ_{cr}, of plate panels subject to compression or shear, respectively, is to be taken as:

$$\sigma_{xcr} = C_x \sigma_{yd}$$

$$\sigma_{ycr} = C_y \sigma_{yd}$$

$$\tau_{cr} = C_\tau \frac{\sigma_{yd}}{\sqrt{3}}$$

18.3 Buckling of stiffeners

18.3.1 Critical compressive stress.

18.3.1.1 The buckling utilisation factor of stiffeners is to be taken as the maximum of the column and torsional buckling mode as given in 18.3.2 and 18.3.3.

18.3.2 Column buckling mode.

18.3.2.1 Stiffeners are to be verified against the column buckling mode as given in 18.3.2.2 with the allowable buckling utilisation factor, η_{allow}, *see* 18.1.2.2. Stiffeners not subjected to lateral pressure and that have a net moment of inertia, I_{net}, complying with 18.3.2.4 have acceptable column buckling strength and need not be verified against 18.3.2.2.

18.3.2.2 The buckling utilisation factor for column buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x + \sigma_b}{\sigma_{yd}}$$

where

σ_b = bending stress at the midspan of the stiffener according to 18.3.2.3, in N/mm^2.

18.3.2.3 The bending stress in the stiffener is equal to:

$$\sigma_b = \frac{M_o + M_1}{1000 Z_{net}} \text{ N/mm}^2$$

where

Z_{net} = net section modulus of stiffener, in cm^3, including effective breadth of plating according to 18.3.4.1

(a) if lateral pressure is applied to the stiffener:

Z_{net} = the section modulus calculated at flange if the lateral pressure is applied on the same side as the stiffener

Z_{net} = the section modulus calculated at attached plate if the lateral pressure is applied on the side opposite to the stiffener

(b) if no lateral pressure is applied on the stiffener:

Z_{net} = the minimum section modulus among those calculated at flange and attached plate

M_1 = bending moment, in Nmm, due to the lateral load P

$$= \frac{P\, s\, l_{stf}^2}{24} 10^3$$

P = lateral load, in kN/m^2

l_{stf} = span of stiffener, in metres, equal to spacing between primary support members

M_o = bending moment, in Nmm, due to the lateral deformation w of stiffener

$= F_E \left(\frac{P_z w}{c_f - P_z}\right)$ where $(c_f - P_z) > 0$

F_E = ideal elastic buckling force of the stiffener, in N

$= \left(\frac{\pi^2}{l_{stf}^2}\right) E\, I_{net} \quad 10^{-2}$

I_{net} = moment of inertia, in cm^4, of the stiffener including effective width of attached plating according to 18.3.4.1. I_{net} is to comply with the following requirement:

$$I_{net} \geq \frac{s\, t_{net}^3}{12} 10^{-4}$$

t_{net} = net thickness of plate flange, to be taken as the mean thickness of the two attached plate panels, in mm

P_z = nominal lateral load, in N/mm^2, acting on the stiffener due to membrane stresses, σ_x, σ_y and τ_1, in the attached plate in way of the stiffener midspan:

$$= \frac{t_{net}}{s}\left(\sigma_{xl}\left(\frac{\pi s}{1000 l_{stf}}\right)^2 + 2 c_y \sigma_y + \sqrt{2}\ \tau_1\right)$$

$$\sigma_{xl} = \sigma_x\left(1 + \frac{A_{net}}{s\, t_{net}}\right) \quad N/mm^2$$

$$\tau_1 = \left[\tau - t_{net}\sqrt{\sigma_{yd} E\left(\frac{m_1}{(1000 l_{stf})^2} + \frac{m_2}{s^2}\right)}\right] \geq 0$$

with m_1 and m_2 taken equal to

$m_1 = 1{,}47 \qquad m_2 = 0{,}49$ for $\frac{1000 l_{stf}}{s} \geq 2{,}0$

$m_1 = 1{,}96 \qquad m_2 = 0{,}37$ for $\frac{1000 l_{stf}}{s} \geq 2{,}0$

A_{net} = net sectional area of the stiffener without attached plating, in mm^2

c_y = factor taking into account the membrane stresses in the attached plating acting perpendicular to the stiffener's axis

$= 0{,}5\,(1 + \psi)$ for $0 \leq \psi \leq 1$

$= \frac{0{,}5}{1 - \psi}$ for $\psi < 0$

ψ = edge stress ratio for Case 2 according to Table 1.18.1

σ_y = membrane compressive stress in the attached plating acting perpendicular to the stiffener's axis, in N/m^2

τ = shear membrane stress in the attached plating, in N/mm^2

w = deformation of stiffener, in mm

$= w_0 + w_1$

w_0 = assumed imperfection, in mm

$= \min\left[\frac{1000 l_{stf}}{250}, \frac{s}{250}, 10\right]$

For stiffeners sniped at both ends w_0 is not to be taken less than the distance from the midpoint of attached plating to the neutral axis of the stiffener calculated with the effective width of the attached plating according to 18.3.4.1

w_1 = deformation of stiffener at midpoint of stiffener span due to lateral load P, in mm. In case of uniformly distributed load w_1 is to be taken as:

$$= \frac{P s\, l_{stf}^4}{384 \cdot E\, I_{net}} 10^5$$

c_f = elastic support provided by the stiffener, in N/mm^2

$$= F_E \frac{\pi^2}{l_{stf}^2}(1 + c_p)\, 10^{-6}$$

$$c_p = \frac{1}{1 + \frac{0{,}91}{c_a}\left(\frac{12 I_{net} 10^4}{s\, t_{net}^3} - 1\right)}$$

$$c_a = \left[\frac{1000 l_{stf}}{2s} + \frac{2s}{1000 l_{stf}}\right]^2 \quad \text{for } l_{stf} \geq \frac{2s}{1000}$$

$$c_a = \left[1 + \left(\frac{1000 l_{stf}}{2s}\right)^2\right]^2 \quad \text{for } l_{stf} < \frac{2s}{1000}$$

18.3.2.4 Stiffeners not subjected to lateral pressure are considered as complying with the requirements of 18.3.2.2 if their net moments of inertia, in cm^4, satisfy the following requirement:

$$I_{net} \geq \frac{100\, P_z\, l_{stf}^2}{\pi^2}\left[\frac{w_0 (e_f - 0{,}5 t_{f-net})}{\eta_{allow}\sigma_{yd} - \sigma_x} + \frac{l_{stf}^2}{E\pi^2} 10^6\right]$$

where

e_f = distance from connection to plate (C as shown in Fig. 1.18.1) to centre of flange, in mm

$= (d_w - 0{,}5 t_{f\text{-}net})$ for bulb flats

$= (d_w + 0{,}5 t_{f\text{-}net})$ for angles and T bars

NOTE
Other parameters are as defined in 18.3.2.3.

18.3.3 **Torsional buckling mode**.

18.3.3.1 The torsional buckling mode is to be verified against the allowable buckling utilisation factor, η_{allow}, *see* 18.1.2.2. The buckling utilisation factor for torsional buckling of stiffeners is to be taken as:

$$\eta = \frac{\sigma_x}{C_T \sigma_{yd}}$$

where

σ_x = compressive axial stress in the stiffener, in N/mm^2, calculated at the attachment point of the stiffener to the plate, in way of the midspan of the stiffener measured along the global x-axis

C_T = torsional buckling coefficient

$= 1{,}0$ for $\lambda_T \leq 0{,}2$

$= \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_T^2}}$ for $\lambda_T > 0{,}2$

$\Phi = 0{,}5\,(1 + 0{,}21\,(\lambda_T - 0{,}2) + \lambda_T^2)$

λ_T = reference degree of slenderness for torsional buckling

$$= \sqrt{\frac{\sigma_{yd}}{\sigma_{ET}}}$$

Table 1.18.2 Moments of inertia

Section property	Flat bars	Bulb flats, angles and T bars
$I_{P\text{-net}}$	$\dfrac{d_w^3\, t_{w\text{-net}}}{3 \times 10^4}$	$\left(\dfrac{A_{w\text{-net}}\,(e_f - 0{,}5t_{f\text{-net}})^2}{3} + A_{f\text{-net}}\, e_f^2\right) 10^{-4}$
$I_{T\text{-net}}$	$\dfrac{d_w\, t_{w\text{-net}}^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_{w\text{-net}}}{d_\omega}\right)$	$\dfrac{(e_f - 0{,}5t_{f\text{-net}})\, t_{w\text{-net}}^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_{w\text{-net}}}{e_f - 0{,}5t_{f\text{-net}}}\right) + \dfrac{b_f\, t_{f\text{-net}}^3}{3 \times 10^4}\left(1 - 0{,}63\,\dfrac{t_{f\text{-net}}}{b_f}\right)$
$I_{\omega\text{-net}}$	$\dfrac{d_w^3\, t_{w\text{-net}}^3}{36 \times 10^6}$	for bulb flats and angles: $\dfrac{A_{f\text{-net}}\, e_f^2\, b_f^2}{12 \times 10^6}\left(\dfrac{A_{f\text{-net}} + 2{,}6A_{w\text{-net}}}{A_{f\text{-net}} + A_{w\text{-net}}}\right)$ for T bars: $\dfrac{b_f^3\, t_{f\text{-net}}\, e_f^2}{12 \times 10^6}$

σ_{ET} = reference stress for torsional buckling, in N/mm²

$$= \frac{E}{I_{p\text{-net}}}\left(\frac{\varepsilon\,\pi^2\, I_{w\text{-net}}\, 10^{-4}}{l_t^2} + 0{,}385 I_{T\text{-net}}\right)$$

$I_{P\text{-net}}$ = net polar moment of inertia of the stiffener about point C, in cm⁴, as shown in Fig. 1.18.1 and Table 1.18.2

$I_{T\text{-net}}$ = net St.Venant's moment of inertia of the stiffener, in cm⁴, as shown in Table 1.18.2

$I_{w\text{-net}}$ = net sectorial moment of inertia of the stiffener about point C, in cm⁶, as shown in Fig. 1.18.1 and Table 1.18.2

ε = degree of fixation

$$1 + 1000\sqrt[4]{\frac{l_t^4}{\dfrac{3}{4}\,\pi^4\, I_{w\text{-net}}\left(\dfrac{s}{t_{net}^3} + \dfrac{4(e_f - 0{,}5t_{f\text{-net}})}{3t_{w\text{-net}}^3}\right)}}$$

l_t = torsional buckling length to be taken equal the distance between tripping supports, in metres, distance from connection to plate (C in Fig. 1.18.1) to centre of flange, in mm

e_f = $(d_w - 0{,}5t_{f\text{-net}})$ for bulb flats
= $(d_w + 0{,}5t_{f\text{-net}})$ for angles and T Bars

net web area, in mm²

$A_{w\text{-net}}$ = $(e_f - 0{,}5t_{f\text{-net}})\, t_{w\text{-net}}$

net flange area, in mm²

$A_{f\text{-net}}$ = $b_f\, t_{f\text{-net}}$.

18.3.4 **Effective breadth of attached plating**.

18.3.4.1 The effective breadth of attached plating of ordinary stiffeners is to be taken as:

b_{eff} = min $(C_x\, s, \chi_s\, s)$

where

$$\chi_s = 0{,}0035\left(\frac{1000 l_{eff}}{s}\right)^3 - 0{,}0673\left(\frac{1000 l_{eff}}{s}\right)^2 + 0{,}4422\left(\frac{1000 l_{eff}}{s}\right) - 0{,}0056 \leq 1{,}0$$

C_x = average reduction factor for buckling of the two attached plate panels, according to Case 1 in Table 1.18.1

l_{stf} = span of stiffener, in metres, equal to spacing between primary support members

l_{eff} = effective span of stiffeners in metres
= l_{stf} if simply supported at both ends
= $0{,}6 l_{stf}$ if fixed at both ends.

18.4 Primary support members

18.4.1 **Buckling of web plate of primary support members in way of openings**.

18.4.1.1 The web plate of primary support members with openings is to be assessed for buckling, based on the combined axial compressive and shear stresses. The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels, as shown in Table 1.18.3. The buckling utilisation factor, η, is to be taken as:

$$\eta = \left(\frac{|\,\sigma_{av}\,|}{C\,\sigma_{yd}}\right)^{e} + \left(\frac{|\,\tau_{av}\,|\sqrt{3}}{C_\tau\,\sigma_{yd}}\right)^{e_\tau}$$

where

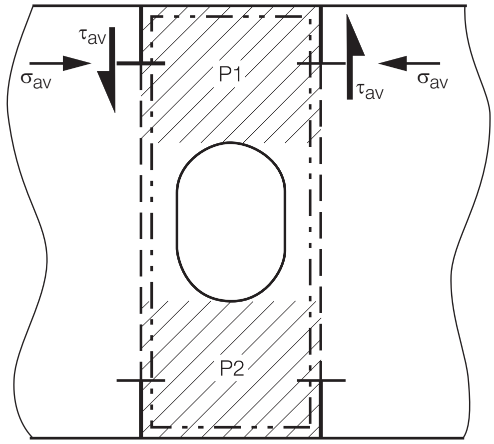
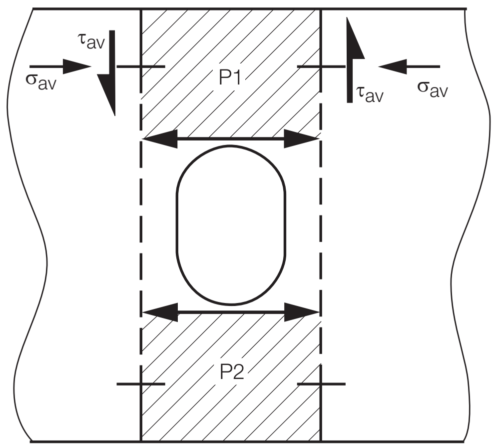
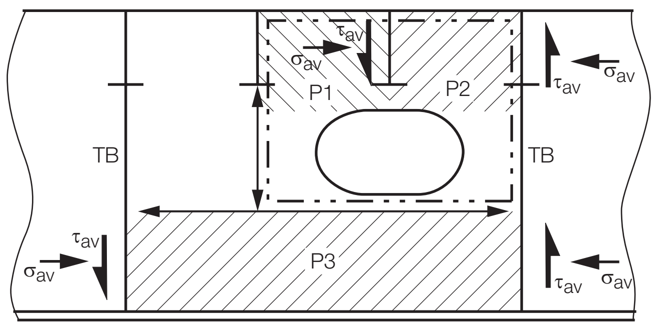
σ_{av} = average compressive stress in the area of web plate being considered according to Case 1, 2 or 3 in Table 1.18.1, in N/mm²

τ_{av} = average shear stress in the area of web plate being considered according to Case 5 or 6 in Table 1.18.1, in N/mm²

e = $1 + C^4$ exponent for compressive stress

e_τ = $1 + C\, C_\tau^2$ exponent for shear stress

Table 1.18.3 Reduction factors

Mode	C_x, C_y	C_τ
(a) Without edge reinforcements 	Separate reduction factors are to be applied to areas P1 and P2 using Case 3 in Table 1.18.1, with edge stress ratio: ψ = 1,0	A common reduction factor is to be applied to areas P1 and P2 using Case 6 in Table 1.18.1 for area marked: 
(b) With edge reinforcements 	Separate reduction factors are to be applied for areas P1 and P2 using: C_x for Case 1 or C_y, for Case 2, *see* Table 1.18.1 with stress ratio ψ = 1,0	Separate reduction factors are to be applied for areas P1 and P2 using Case 5 in Table 1.18.1
(c) Example of hole in web 	Panels P1 and P2 are to be evaluated in accordance with (a). Panel P3 is to be evaluated in accordance with (b)	
NOTE Web panels to be considered for buckling in way of openings are shown shaded and numbered P1, P2, etc.		

C = C_x reduction factor according to Case 1 or 3 in Table 1.18.1

C = C_y reduction factor according to Case 2 in Table 1.18.1

C_τ = reduction factor according to Case 5 or 6 in Table 1.18.1.

18.4.1.2 The reduction factors, C_x or C_y in combination with C_τ, of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 1.18.3.

18.5 Other structures

18.5.1 **Struts, pillars and cross ties**.

18.5.1.1 The critical buckling stress for axially compressed struts, pillars and cross ties is to be taken as the lesser of the column and torsional critical buckling stresses. The buckling utilisation factor, η, is to be taken as:

$$\eta = \frac{\sigma_{av}}{\sigma_{cr}}$$

where

σ_{av} = average axial compressive stress in the member, in N/mm^2

σ_{cr} = minimum critical buckling stress according to 18.5.1.2, in N/mm^2.

18.5.1.2 The critical buckling stress in compression for each mode is to be taken as:

$$\sigma_{cr} = \sigma_e \text{ for } \sigma_E \leq 0{,}5\sigma_{yd}$$

$$\sigma_{cr} = \left(1 - \frac{\sigma_{yd}}{4\sigma_E}\right)\sigma_{yd} \text{ for } \sigma_E > 0{,}5\sigma_{yd}$$

where

σ_E = elastic compressive buckling stress, in N/mm^2, given for each buckling mode, *see* 18.5.1.3 to 18.5.1.5.

18.5.1.3 The elastic compressive column buckling stress of pillars subject to axial compression is to be taken as:

$$\sigma_E = 0{,}001 E\, f_{end} \frac{I_{net50}}{A_{pill\text{-}net50}\, l_{pill}^2} \quad \text{N/mm}^2$$

where

I_{net50} = net moment of inertia about the weakest axis of the cross-section, in cm^4

$A_{pill\text{-}net50}$ = net cross-sectional area of the pillar, in cm^2

f_{end} = end constraint factor:
1,0 where both ends are pinned
2,0 where one end is pinned and the other end is fixed
4,0 where both ends are fixed
A pillar end may be considered fixed when effective brackets are fitted. These brackets are to be supported by structural members with greater bending stiffness than the pillar
Column buckling capacity for cross tie shall be calculated using f_{end} equal to 2,0

l_{pill} = unsupported length of the pillar, in metres.

18.5.1.4 The elastic torsional buckling stress, σ_{ET}, with respect to axial compression of pillars is to be taken as:

$$\sigma_{ET} = \frac{G\, I_{sv\text{-}net50}}{I_{pol\text{-}net50}} + \frac{0{,}001 f_{end}\, E\, c_{warp}}{I_{pol\text{-}net50}\, l_{pill}^2} \quad \text{N/mm}^2$$

where

G = shear modulus
$= \dfrac{E}{2\,(1+\nu)}$

$I_{sv\text{-}net50}$ = net St.Venant's moment of inertia, in cm^4, *see* Table 1.18.4

$I_{pol\text{-}net50}$ = net polar moment of inertia about the shear centre of cross-section
$= I_{y\text{-}net50} + I_{z\text{-}net50} + A_{net50}\,(y_0^2 + z_0^2)$ cm^4

f_{end} = end constraint factor:
1,0 where both ends are pinned
2,0 where one end is pinned and the other end is fixed
4,0 where both ends are fixed
Elastic torsional buckling capacity for cross tie shall be calculated using f_{end} equal to 2,0

c_{warp} = warping constant, in cm^6, *see* Table 1.18.4

l_{pill} = unsupported length of the pillar, in metres

y_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

z_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

A_{net50} = net cross-sectional area, in cm^2

$I_{y\text{-}net50}$ = net moment of inertia about y-axis, in cm^4

$I_{z\text{-}net50}$ = net moment of inertia about z-axis, in cm^4.

18.5.1.5 For cross-sections where the centroid and the shear centre do not coincide, the interaction between the torsional and column buckling mode is to be examined. The elastic torsional/column buckling stress with respect to axial compression is to be taken as:

$$\sigma_{ETF} = \frac{1}{2\zeta}\left[(\sigma_E + \sigma_{ET}) - \sqrt{(\sigma_E + \sigma_{ET})^2 - 4\zeta\,\sigma_E\,\sigma_{ET}}\right]$$

where

$$\zeta = 1 - \frac{(y_0^2 + z_0^2)\,A_{net50}}{I_{pol\text{-}net50}}$$

y_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

z_0 = position of shear centre relative to the cross-sectional centroid, in cm, *see* Table 1.18.4

A_{net50} = net cross-sectional area, in cm^2

$I_{pol\text{-}net50}$ = net polar moment of inertia about the shear centre of cross-section, as defined in 18.5.1.4

σ_{ET} = elastic torsional buckling stress, as defined in 18.5.1.4

σ_E = elastic column compressive buckling stress, as defined in 18.5.1.3.

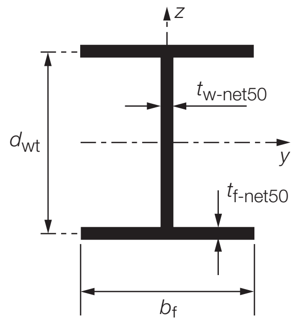
18.5.2 **Corrugated bulkheads**.

18.5.2.1 Local buckling of a unit flange of corrugated bulkheads is to be controlled according to 18.2.1.1, for Case 1, as shown in Table 1.18.1, applying stress ratio ψ = 1,0.

18.5.2.2 The overall buckling failure mode of corrugated bulkheads subjected to axial compression is to be checked for column buckling according to 18.5.1 (e.g., horizontally corrugated longitudinal bulkheads, vertically corrugated bulkheads subject to localised vertical forces). End constraint factor corresponding to pinned ends is to be applied, except for fixed end support to be used in way of stool with width exceeding two times the depth of the corrugation.

Table 1.18.4 Cross-sectional properties

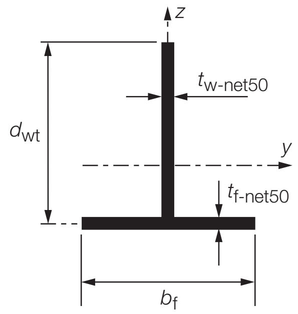
Double symmetrical sections



$$I_{sv\text{-net50}} = \frac{1}{3}\left(2b_f\, t_{f\text{-net50}}^3 + d_w\, t_{w\text{-net50}}^3\right) 10^{-4} \quad \text{cm}^4$$

$$c_{warp} = \frac{d_{wt}^2\, b_f^3\, t_{f\text{-net50}}}{24} 10^{-6} \quad \text{cm}^6$$

Single symmetrical sections

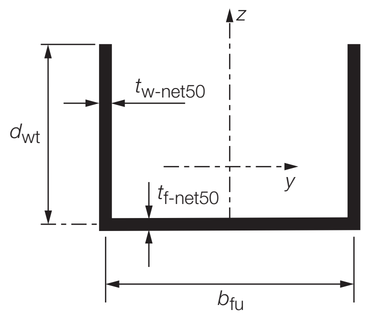


$$I_{sv\text{-net50}} = \frac{1}{3}\left(b_f\, t_{f\text{-net50}}^3 + d_{wt}\, t_{w\text{-net50}}^3\right) 10^{-4} \quad \text{cm}^4$$

$$y_0 = 0 \text{ cm}$$

$$z_0 = \frac{0{,}5 d_{wt}^2\, t_{w\text{-net50}}}{d_{wt}\, t_{w\text{-net50}} + b_f\, t_{f\text{-net50}}} 10^{-1} \quad \text{cm}$$

$$c_{warp} = \frac{b_f^3\, t_{f\text{-net50}}^3 + 4d_{wt}^3\, t_{w\text{-net50}}^3}{144} 10^{-6} \quad \text{cm}^6$$

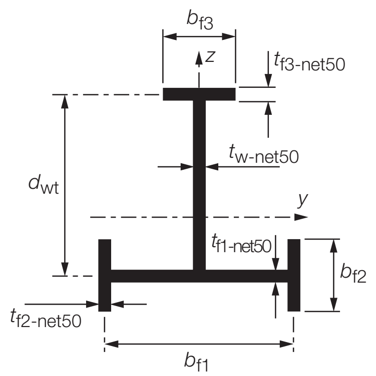


$$I_{sv\text{-net50}} = \frac{1}{3}\left(b_{fu}\, t_{f\text{-net50}}^3 + 2d_{wt}\, t_{w\text{-net50}}^3\right) 10^{-4} \quad \text{cm}^4$$

$$y_0 = 0 \text{ cm}$$

$$z_0 = \frac{d_{wt}^2\, t_{w\text{-net50}}\, 10^{-1}}{2d_{wt}\, t_{w\text{-net50}} + b_f\, t_{f\text{-net50}}} - \frac{0{,}5 d_{wt}^2\, t_{w\text{-net50}}\, 10^{-1}}{d_{wt}\, t_{w\text{-net50}} + b_{fu}\, t_{f\text{-net50}}/6} \quad \text{cm}$$

$$c_{warp} = \frac{b_{fu}^2\, d_{wt}^3\, t_{w\text{-net50}}\left(3d_{wt}\, t_{w\text{-net50}} + 2b_{fu}\, t_{f\text{-net50}}\right)}{12\left(6d_w\, t_{w\text{-net50}} + b_{fu}\, t_{f\text{-net50}}\right)} 10^{-6} \quad \text{cm}^6$$



$$I_{sv\text{-net50}} = \frac{1}{3}\left(b_{f1}\, t_{f1\text{-net50}}^3 + 2b_{f2}\, t_{f2\text{-net50}}^3 + b_{f3}\, t_{f3\text{-net50}}^3 + d_{wt}\, t_{w\text{-net50}}^3\right) 10^{-4} \quad \text{cm}^4$$

$$y_0 = 0 \text{ cm}$$

$$z_0 = z_s - \frac{\left(b_{f3}\, d_{wt}\, t_{f3\text{-net50}} + 0{,}5 d_{wt}^2\, t_{w\text{-net50}}\right) 10^{-1}}{d_{wt}\, t_{w\text{-net50}} + b_{f1}\, t_{f1\text{-net50}} + 2b_{f2}\, t_{f2\text{-net50}} + b_{f3}\, t_{f3\text{-net50}}} \quad \text{cm}$$

$$c_{warp} = I_{f1}\, z_s^2 + \frac{I_{f2}\, b_{f1}^2}{200} + I_{f3}\left(\frac{d_{wt}}{10} - z_s\right)^2 \quad \text{cm}^6$$

$$I_{f1} = \left(\frac{\left(b_{f1} - t_{f2\text{-net50}}\right)^3 t_{f1\text{-net50}}}{12} + \frac{b_{f2}\, t_{f2\text{-net50}}\, b_{f1}^2}{2}\right) 10^{-4} \quad \text{cm}^4$$

$$I_{f2} = \frac{b_{f2}^3\, t_{f2\text{-net50}}}{12} 10^{-4} \quad \text{cm}^4$$

$$I_{f3} = \frac{b_{f3}^3\, t_{f3\text{-net50}}}{12} 10^{-4} \quad \text{cm}^4$$

$$z_s = \frac{I_{f3}\, d_{wt}}{I_{f1} + I_{f3}} 10^{-1} \quad \text{cm}$$

NOTE
All dimensions of thickness, breadth and depth are in mm.
Cross-sectional properties not covered by this Table are to be obtained by direct calculation.

Section 19
Fatigue

19.1 General

19.1.1 The fatigue life is to be assessed in accordance with the LR ShipRight Procedure for Ship Units and Pt 4, Ch 5,5.

19.2 Factors of safety on fatigue life

19.2.1 The factors of safety defined in Pt 4, Ch 5,5.6 are to be applied to the hull structure. Examples are given in Table 1.19.1.

Table 1.19.1 Example factors of safety on fatigue life for hull structure

Location	Inspectable/repairable?	Substantial consequence of failure?	Fatigue life factor
Bilge keel in way of ballast tanks or void spaces	Wet (OIWS)	No (no pollution)	2
Bilge keel	Wet (OIWS)	Yes (pollution)	4
LNG pump tower attachment points (top dome penetrations and bottom base support penetrations)	No (covered by insulation)	Yes (loss of primary and secondary barriers)	10
LNG pump tower	Dry	Yes (loss of primary and secondary barriers)	2
Bottom longitudinal stiffener end connections in way of ballast tanks or void spaces	Dry	No (no pollution)	1
Bottom longitudinal stiffener end connections	Dry	Yes (pollution)	2
Double hull hopper knuckle connection	Dry	No (no pollution)	1
Stiffened plate module supports attachment to upper deck	Dry	No	1
Lattice module supports attachment to upper deck	Dry	Yes	2
Lattice module supports attachment to upper deck with single member redundancy	Dry	No	1
Hull structure bounding membrane LNG tanks	Equivalent to wet (repair will damage insulation)	No	2
Penetrations in upper deck for LNG tank domes	No (covered by seal)	No	3

Section 1 General

1.1 Application

1.1.1 This Section provides the design load combinations for the scantling calculations. The loads cover load scenarios for all modes of operation dividing the loads into static load components, dynamic load components, sloshing loads and impact loads. The loads are applicable to ship units of conventional hull form and proportions. If the form and proportions of the hull are outside of those for conventional ship type units then special consideration of the ship motions may be required. Details of the proposed hull design are to be submitted for consideration, and it is recommended this is done at as early a stage as possible.

1.1.2 The values of motions, accelerations and sloshing loads may be derived from direct calculation or obtained from model testing. These should be assessed in relation to Lloyd's Register's (LR) own direct calculation procedures.

1.2 Definitions

1.2.1 **Coordinate system**.

1.2.1.1 The applied coordinate system used within these Rules is defined with respect to the right-hand coordinate system.

1.2.2 **Sign conventions**.

1.2.2.1 Positive motions, as shown in Fig. 2.1.1, are defined as:
(a) positive surge is translation along positive x-axis (forward);
(b) positive sway is translation along positive y-axis (towards port side of vessel);
(c) positive heave is translation along positive z-axis (upwards);
(d) positive roll is starboard down and port side up;
(e) positive pitch is bow down and stern up;
(f) positive yaw is bow rotating towards port side of vessel and stern towards starboard side.

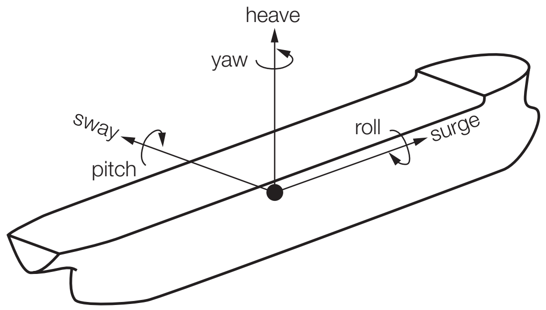
1.2.2.2 Positive accelerations are defined as:
(a) positive longitudinal acceleration is acceleration along positive x-axis (forward);
(b) positive transverse acceleration is acceleration along positive y-axis (towards port side of vessel);
(c) positive vertical acceleration is acceleration along positive z-axis (upwards).

1.2.2.3 The sign convention of positive vertical hull girder shear force is shown in Fig. 2.1.2.

1.2.2.4 The sign conventions of positive hull girder bending moments are shown in Fig. 2.1.3 and Fig. 2.1.4, and are defined as:
(a) positive vertical bending moment is a hogging moment and negative vertical bending moment is a sagging moment;
(b) positive horizontal bending moment is tension on the starboard side and compression on the port side.

1.2.3 **Density**.

1.2.3.1 The density is not to be taken as less than minimum density value, as defined in Table 2.1.1.



NOTE
This figure shows the rotation axis and not the coordinate system

Fig. 2.1.1 Definition of positive motions

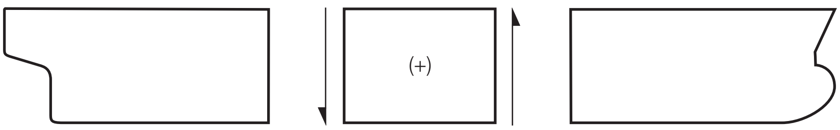


Fig. 2.1.2 Positive vertical shear force

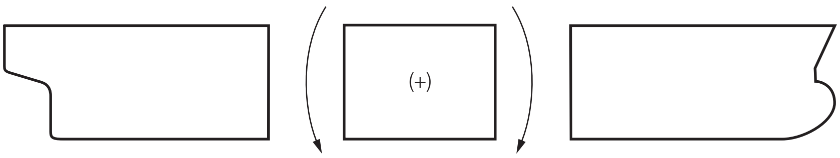


Fig. 2.1.3 Positive vertical bending moment

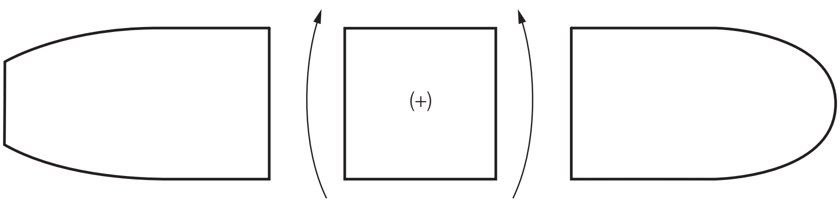


Fig. 2.1.4 Positive horizontal bending moment

Table 2.1.1 Minimum density of liquid for strength and fatigue assessment

Liquid	Scantling and strength	Fatigue	Sloshing	Ultimate strength
Cargo oil	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual
Ballast water	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3
Sea-water, ρ_{sw}	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3	1,025 t/m^3
Condensate	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual
Chemicals	The greater of 1,025 t/m^3 or actual	Mean	The greater of 1,025 t/m^3 or actual	The greater of 1,025 t/m^3 or actual
Liquefied gas	Maximum density of the liquefied gas	Mean density of the liquefied gas	Maximum density of the liquefied gas	Maximum density of the liquefied gas

■ Section 2 Static load components

2.1 Symbols

2.1.1 For the purposes of this Section, the following symbols apply:

L = Rule length, in metres, as defined in Pt 4, Ch 1,5
B = moulded breadth, in metres, as defined in Pt 4, Ch 1,5
D = moulded depth, in metres, as defined in Pt 4, Ch 1,5
C_{wv} = wave coefficient, as defined in 3.1
C_b = block coefficient, as defined in Pt 4, Ch 1,5
ρ = density, tonnes/m^3, as defined in 1.2.3
g = acceleration due to gravity, 9,81 m/s^2
$M_{sw\text{-}perm\text{-}sea}$ = permissible hull girder hogging and sagging still water bending moment envelopes for transit condition, in kNm
$M_{sw\text{-}perm\text{-}oper}$ = permissible hull girder hogging and sagging still water bending moment envelopes for operational condition, in kNm
$M_{sw\text{-}perm\text{-}maint}$ = permissible hull girder hogging and sagging still water bending moment envelopes for inspection/maintenance condition, in kNm
$Q_{sw\text{-}perm\text{-}sea}$ = permissible hull girder positive and negative still water shear force limits for transit condition, in kN
$Q_{sw\text{-}perm\text{-}oper}$ = permissible hull girder positive and negative still water shear force limits for operational condition, in kN
$Q_{sw\text{-}perm\text{-}maint}$ = permissible hull girder positive and negative still water shear force limits for inspection/maintenance condition, in kN
l_{tk} = length of cargo tank under consideration, in metres
T_{sc} = deep load draught, in metres, is the maximum draught on which the scantlings are based
V_{CT} = volume of centreline cargo tank under consideration, in m^3
V_{ST} = volume of side cargo tank under consideration, in m^3.

2.2 Static hull girder loads

2.2.1 **Permissible hull girder still water bending moment and shear force**.

2.2.1.1 The designer is to provide the permissible hull girder hogging and sagging still water bending moment limits for the transit condition, $M_{sw\text{-}perm\text{-}sea}$, operational condition, $M_{sw\text{-}perm\text{-}oper}$, and inspection/maintenance condition, $M_{sw\text{-}perm\text{-}maint}$.

2.2.1.2 The designer is to provide the permissible hull girder positive and negative still water shear force limits for the transit condition, $Q_{sw\text{-}perm\text{-}sea}$, operational condition, $Q_{sw\text{-}perm\text{-}oper}$, and inspection/maintenance condition, $Q_{sw\text{-}perm\text{-}maint}$.

2.2.1.3 The permissible hull girder still water bending moment and shear force limits are to be given at each transverse bulkhead in the cargo area, at the middle of cargo tanks and at significant structural discontinuities, including internal turrets.

2.2.1.4 The permissible hull girder still water bending moment envelope is given by linear interpolation between values at the longitudinal position given in 2.2.1.3.

2.2.1.5 The permissible hull girder still water bending moment and shear force envelopes are to be included in the loading manual as required in Pt 4, Ch 3,1.3 and 1.4.

2.2.2 **New build**.

2.2.2.1 Loadings patterns representative of the loading conditions for all modes of operation are to be assessed considering those cases which will induce the largest forces in the hull structure.

2.2.2.2 The static loading conditions to be used in combinations with the applicable dynamic loads in Section 6 should be appropriate for the intended operation of the unit. In general, they should include:

- homogeneous full load;
- emergency ballast;
- ‘chequer-board’ loading;
- all cargo tanks full with any two adjacent cargo tanks empty (this is to allow repair of any tank boundary whilst in service); and
- all cargo tanks empty with any one cargo tank full;
- most onerous partial loading conditions as applicable.

2.2.3 **Conversions and redeployments**.

2.2.3.1 The loading conditions should be as for new build units, *see* 2.2.2, suitably modified to take account of the following:

- Loading limitations previously assigned prior to conversion/redeployment.
- Where the loading conditions defined for new build units are too restrictive or too onerous.

2.3 Local static loads

2.3.1 **General**.

2.3.1.1 The following static loads are to be considered, as appropriate:

(a) static sea pressure;
(b) static tank pressure;
(c) tank overpressure, in addition to the static tank pressure when appropriate;
(d) static deck load;
(e) accidental pressure.

2.3.2 **Static pressure**.

2.3.2.1 The static pressures for the static loads defined in 2.3.1.1 are given in Table 2.2.1.

2.3.3 **Static deck loads from heavy units**.

2.3.3.1 The scantlings of structure in way of heavy units of cargo and equipment are to consider gravity forces acting on the mass. The load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, F_{stat}, is to be taken as:

$$F_{stat} = m_{un} g \quad \text{kN}$$

where

m_{un} = mass of unit, in tonnes.

Table 2.2.1 Static load pressures

Load cases		Static pressure, in kN/m^2
(a)	Static sea pressure	$P_{hys} = \rho_{sw}\, g\, (T_{LC} - z)$
(b)	Static tank pressure	$P_{in\text{-}tk} = \rho\, g\, z_{top}$
(c)	Static tank pressure + overpressure	$P_{in\text{-}air} = \rho_{sw}\, g\, z_{air}$ $P_{in\text{-}test} = \max\,(\rho_{sw}\, g\, z_{test},\ \rho_{sw}\, g\, z_{top} + P_{valve})$
(d)	Static deck pressure	$P_{stat} = P_{deck}$
(e)	Accidental pressure	$P_{in\text{-}flood} = \rho_{sw}\, g\, z_{fd}$

Symbols

z	=	vertical coordinate of load point, in metres, and is not to be greater than T_{LC}, *see* Fig. 2.2.1
ρ_{sw}	=	density of sea-water, 1,025 tonnes/m^3
T_{LC}	=	draught in the loading condition being considered, in metres
z_{top}	=	vertical distance from highest point of tank, excluding small hatchways, to the load point, *see* Fig. 2.2.1, in metres
z_{air}	=	vertical distance from top of air pipe or overflow pipe to the load point, whichever is the lesser, *see* Fig. 2.2.1, in metres
	=	$z_{top} + h_{air}$
h_{air}	=	height of air pipe or overflow pipe, in metres, is not to be taken less than 0,76 m above highest point of tank, excluding small hatchways. For tanks with tank top below the weather deck, the height of air pipe or overflow pipe is not to be taken less than 0,76 m above deck at side, unless a lesser height is approved by the Flag Administration. *See also* Fig. 2.2.1
z_{fd}	=	vertical distance from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations or to freeboard deck if the damage waterline is not given, in metres
z_{test}	=	vertical distance to the load point is to be taken as defined in Table 2.2.2
P_{valve}	=	setting of pressure relief valve, if fitted, is not to be taken less than 25 kN/m^2
P_{deck}	=	uniformly distributed pressure on lower decks and decks within superstructures, including platform decks in the main engine room and for other spaces with heavy machinery components, in kN/m^2. P_{deck} is not to be taken less than 16 kN/m^2

NOTE
1. The added overpressure due to sustained liquid through the air pipe or overflow pipe in the case of overfilling, P_{drop}, is to be taken as 25 kN/m^2. Additional calculations may be required where piping arrangements may lead to a higher pressure drop, e.g., long pipes or arrangements such as bends and valves.

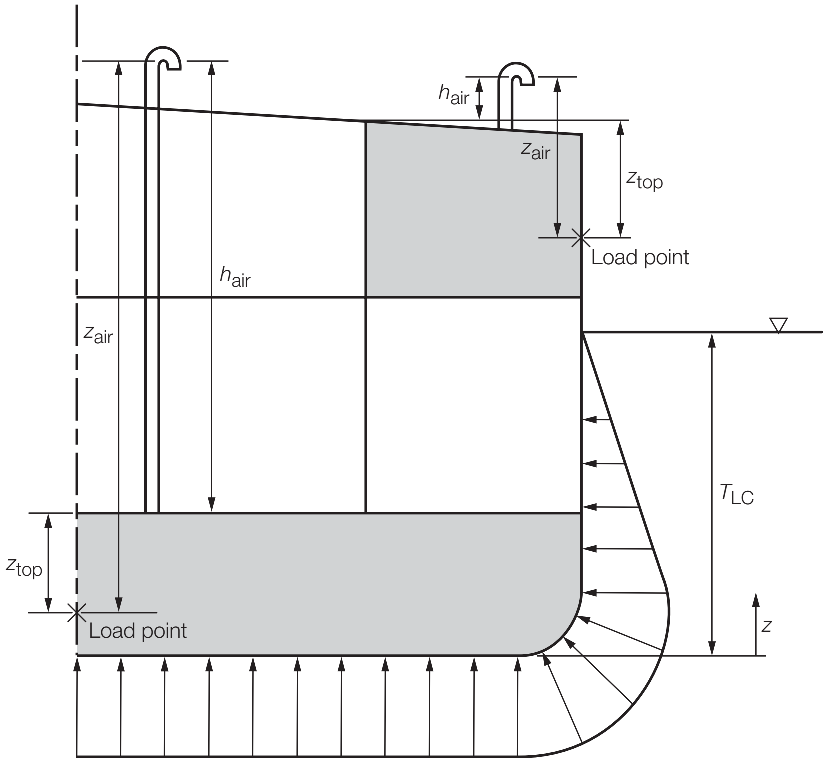


Fig. 2.2.1 Static sea pressure, pressure-heads and distances of static tank pressure

Table 2.2.2 Testing load height

Compartment or structure to be tested	Testing load height, in metres
Cargo tanks and other tanks designed for liquid filling, including double bottom tanks, hopper side tanks, topside tanks, double side tanks, deep tanks, fuel oil bunkers, slop tanks, fresh water tanks, lube oil tanks, fore and after peaks used as tanks and/or fitted with air pipe. Cofferdams	The greater of the following: $z_{test} = z_{top} + h_{air}$ $z_{test} = z_{top} + 2,4$ $z_{test} = z_{top} + z_{pv}$
Fore and aft peaks not used as tanks and not fitted with air pipe	To be tested for tightness, *see* Note
Watertight doors below freeboard deck	To be tested for tightness, *see* Note
Chain locker	$z_{test} = z_{top}$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure
Symbols are as defined in Table 2.2.1	
z_{pv} = equivalent head of pressure safety valve, in metres = $10P_{pv}$ P_{pv} = setting pressure, in bar, of pressure safety valve where applicable	
NOTE When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.	

Section 3
Dynamic load components

3.1 Symbols

3.1.1 For the purposes of this Section, the following symbols apply:

L = Rule length, in metres, as defined in Pt 4, Ch 1,5

B = moulded breadth, in metres, as defined in Pt 4, Ch 1,5

D = moulded depth, in metres, as defined in Pt 4, Ch 1,5

C_b = block coefficient, as defined in Pt 4, Ch 1,5

C_{wv} = wave coefficient to be taken as:

$= 0{,}0412L + 4{,}0$ for $L < 90$

$= 10{,}75 - \left(\dfrac{300 - L}{100}\right)^{\frac{3}{2}}$ for $90 \leq L \leq 300$

$= 10{,}75$ for $300 < L \leq 350$

$= 10{,}75 - \left(\dfrac{L - 350}{150}\right)^{\frac{3}{2}}$ for $350 < L \leq 500$

GM = metacentric height, in metres, as defined in 3.2.3.1

k_r = roll radius of gyration, in metres, as defined in 3.2.3.1

f_{bk} = 1,2 for units without bilge keel
1,0 for units with bilge keel

T_θ = roll period, in seconds, as defined in 3.5.2.1

θ = roll amplitude, in degrees, as defined in 3.5.2.2

T_φ = pitch period, in seconds, as defined in 3.5.3.1

φ = pitch amplitude, in degrees, as defined in 3.5.3.2

R_{roll} $= z - \left(\dfrac{D}{4} + \dfrac{T_{LC}}{2}\right)$ or $z - \left(\dfrac{D}{2}\right)$,
whichever is the greater, in metres

R_{pitch} = pitch radius and is to be taken as the greater of

$z - \left(\dfrac{D}{4} + \dfrac{T_{LC}}{2}\right)$ or $z - \left(\dfrac{D}{2}\right)$, in metres

f_T $= \dfrac{T_{LC}}{T_{sc}}$

T_{sc} = deep load draught, in metres

T_{LC} = draught in the loading condition being considered, in metres

a_0 = common acceleration parameter, as defined in 3.6.2.1

a_v = envelope vertical acceleration, in m/s^2, as defined in 3.6.3.1, at tank centre of gravity

a_t = envelope transverse acceleration, in m/s^2, as defined in 3.6.4.1, at tank centre of gravity

a_{lng} = envelope longitudinal acceleration, in m/s^2, as defined in 3.6.5.1, at tank centre of gravity

a_{heave} = vertical acceleration due to heave, is to be taken as:

$= a_0\, g$ m/s^2

$a_{pitch\text{-}z}$ = vertical acceleration due to pitch, is to be taken as:

$= \left(0{,}3 + \dfrac{L}{325}\right) \varphi \left(\dfrac{\pi}{180}\right)\left(\dfrac{2\pi}{T_\varphi}\right)^2 |x - 0{,}45L|$ m/s^2

$a_{roll\text{-}z}$ = vertical acceleration due to roll, is to be taken as:

$= 1{,}2\theta \left(\dfrac{\pi}{180}\right)\left(\dfrac{2\pi}{T_\theta}\right)^2 |y|$ m/s^2

a_{sway} = transverse acceleration due to sway and yaw, is to be taken as:

$= 0{,}3g\, a_0$ m/s^2

$a_{roll\text{-}y}$ = transverse acceleration due to roll, is to be taken as:

$= \theta \left(\dfrac{\pi}{180}\right)\left(\dfrac{2\pi}{T_\theta}\right)^2 R_{roll}$ m/s^2

a_{surge} = longitudinal acceleration due to surge, is to be taken as:

$= 0{,}2g\, a_0$ m/s^2

$a_{pitch\text{-}x}$ = longitudinal acceleration due to pitch, is to be taken as:

$= \varphi \left(\dfrac{\pi}{180}\right)\left(\dfrac{2\pi}{T_\varphi}\right)^2 R_{pitch}$ m/s^2

ρ = density, tonnes/m^3, as defined in 1.2.3

g = acceleration due to gravity, 9,81 m/s^2

x = longitudinal coordinate of load point under consideration, in metres

y = transverse coordinate of load point under consideration, in metres

z = vertical coordinate of load point under consideration, in metres

x_0 = longitudinal coordinate of reference point, for dynamic tank pressures is to be taken as the middle of the tank length at the top of the tank, in metres

y_0 = transverse coordinate of reference point, for dynamic tank pressures is to be taken as the middle of the tank breadth at the top of the tank, in metres

z_0 = vertical coordinate of reference point, for dynamic tank pressures is to be taken as the highest point in the tank, in metres

f_{prob} = probability factor, as defined in 3.4, as appropriate

$f_{Env\text{-}pitch}$ = environmental factor due to pitch motion, as defined in 3.3.2 and 3.5.3

$f_{Env\text{-}av}$ = environmental factor due to vertical acceleration, as defined in 3.3.2 and 3.6.3

$f_{Env\text{-}at}$ = environmental factor due to transverse acceleration, as defined in 3.3.2 and 3.6.4

$f_{Env\text{-}alng}$ = environmental factor due to longitudinal acceleration, as defined in 3.3.2 and 3.6.5

$f_{Env\text{-}Mwv}$ = environmental factor due to vertical wave bending moment, as defined in 3.3.2 and 3.7.1

$f_{Env\text{-}Mwv\text{-}h}$ = environmental factor due to horizontal wave bending moment, as defined in 3.3.2 and 3.7.1

$f_{Env\text{-}Qwv}$ = environmental factor due to vertical wave shear force, as defined in 3.3.2 and 3.7.2

$f_{Env\text{-}Pex\text{-}dyn}$ = environmental factor due to dynamic wave pressure, as defined in 3.3.2 and 3.8.2.

3.2 General

3.2.1 **Basic components**.

3.2.1.1 Formulae for unit loads, motions and accelerations are given in this sub-Section. Values calculated in accordance with the LR ShipRight Procedure for Ship Units may be used instead.

3.2.1.2 Formulae for the envelope value of the basic dynamic load components are also given. The basic load components are:
(a) vertical wave bending moment and shear force;
(b) horizontal wave bending moment;
(c) dynamic wave pressure;
(d) dynamic tank pressures.

3.2.2 **Envelope load values**.

3.2.2.1 The envelope loads for scantling requirements and strength assessment are based on the specific return period given in Table 2.3.3.

3.2.3 **Metacentric height and roll radius of gyration for FPSO**.

3.2.3.1 The metacentric height, *GM*, and roll radius of gyration, k_r, should be calculated for typical loading conditions as indicated in Table 2.3.1. For the initial design of units storing oil in bulk (e.g., FPSOs), the values in Table 2.3.1 may be used. The values in Table 2.3.1 for deep draught condition may be used for the initial design of units for the flooded load scenario, *see* 5.1.

3.3 Environmental factors

3.3.1 The environmental factors are used to derive the dynamic load components for the intended site-specific condition and for the transit condition.

3.3.2 For initial design purposes, the environmental factors considering motion are specified in Table 2.3.2. For sites not included in Table 2.3.2, the factors are to be calculated in accordance with the LR ShipRight Procedure for Ship Units.

3.3.3 The environmental factors for the operational condition may be used for the initial design of units for the inspection/maintenance case. The environmental factors for the deep draught for the operational condition may be used for the initial design of units for the flooded case.

3.4 Return periods and probability factor, f_{prob}

3.4.1 For each load condition, the environmental loads for scantling requirements and strength assessment are to be determined at the return periods specified in Table 2.3.3.

3.4.2 In no case are the environmental loads used for the assessment of the hull structure for on-site operation, inspection/maintenance, restricted service area transit, delivery voyage and flooding to be less than 50 per cent of the 25-year return period dynamic loads defined for unrestricted worldwide transit service.

3.4.3 Environmental loads derived for the same wave environment, but at a different return period, may be adjusted to the required return period by use of the probability factor f_{prob}. Therefore, when the environmental loads are derived for the return periods specified in Table 2.3.3, f_{prob} is to be taken as equal to 1. Probability factors should be derived in accordance with the LR ShipRight Procedure for Ship Units.

3.4.4 The site-specific environmental factors, given in Table 2.3.2, give 100-year return period loads for the locations specified using all-year wave data. Therefore, when using these factors for the on-site operation condition, f_{prob} is to be taken as equal to 1.

3.4.5 At the request of the Owner and when consistent with the operational philosophy of the unit, seasonal environmental data may be used to derive the environmental loads for the inspection/maintenance condition. Alternatively, the all-year loads derived for the on-site operation condition may be used for the inspection/maintenance assessment, in conjunction with the probability factor derived to account for the difference between all-year loads and seasonal loads.

3.4.6 In no case are the environmental loads used for the assessment of the hull structure for on-site operation, inspection/maintenance and flooding in a harsh environment to be less than the 25-year return period dynamic loads defined for unrestricted worldwide transit, calculated for a vessel of the same particulars with metacentric height, GM, and roll radius of gyration, k_r, taken from Table 2.3.1.

Table 2.3.1 ***GM* and k_r**

Condition	T_{LC}	*GM*	k_r
Deep draught condition, usually a full load condition	above $0{,}9T_{sc}$	$0{,}12B$	$0{,}35B$
Partial load draught condition, usually a part load-part ballast condition	$0{,}6T_{sc}$	$0{,}24B$	$0{,}40B$
Light draught condition, usually a ballast condition	$0{,}5T_{sc}$	$0{,}33B$	$0{,}45B$
NOTE Values for intermediate draughts may be calculated by linear interpolation.			

Table 2.3.2 Environmental factors

Unit size and operating condition	Environment *see* Note 2,	Draught	f_{Env}	f_{Env}	f_{Env}	f_{Env}	f_{Env}	f_{Env}	f_{Env}	$f_{Env\text{-}Pex\text{-}dyn}$, *see* Note 1		
			Pitch	a_v	a_t	a_{lng}	M_{wv}	$M_{wv\text{-}h}$	Q_{wv}	at, and aft of, midship	at 0,85L	at FP
Aframax or VLCC Transit	Unrestricted worldwide	N/A	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Aframax Weather vaning	West of Shetland Is.	Deep Light	1,3 1,3	0,8 0,8	1,2 1,5	1,4 1,2	1,7 1,3	0,8 1,0	2,0 2,0	1,0 1,0	1,2 1,0	1,6 1,6
	North Sea	Deep Light	1,2 1,2	0,5 0,7	1,2 1,5	1,4 1,2	1,6 1,2	0,8 1,0	1,75 1,75	0,75 1,0	1,0 1,0	1,6 1,6
	Brazil Campos Basin	Deep Light	0,6 0,6	0,5 0,5	1,0 1,65	0,65 0,6	0,75 0,5	0,5 1,0	0,75 0,8	0,5 0,8	0,5 0,75	0,8 0,75
	Western Australia (non-cyclonic)	Deep Light	0,5 0,5	0,5 0,5	0,65 0,75	0,6 0,5	0,65 0,5	0,55 0,55	0,7 0,7	0,5 0,5	0,5 0,5	0,75 0,7
VLCC Weather vaning	Brazil Campos Basin	Deep Light	0,55 0,60	0,50 0,50	0,50 0,50	0,50 0,65	0,60 0,50	0,50 0,50	0,90 0,65	0,60 0,55	0,60 0,55	0,70 0,60
	Western Australia (non-cyclonic)	Deep Light	0,50 0,50	0,50 0,50	0,50 0,50	0,50 0,55	0,50 0,50	0,50 0,50	0,70 0,60	0,60 0,50	0,60 0,50	0,60 0,55
VLCC spread moored	Nigeria	Deep light	0.50 0,50	0,50 0,50	0,50 0,50	0,50 0,50	0,50 0,50	0,50 0,50	0,50 0,50	0,50 0,50	0,50 0,50	0,50 0,50

NOTES

1. Values at intermediate locations may be calculated by linear interpolation. The values for weather vaning units are applicable to units that vane about the bow.
2. The geographic locations of the sites at which long-term environmental data has been used to derive the site-specific environmental factors are shown as follows:

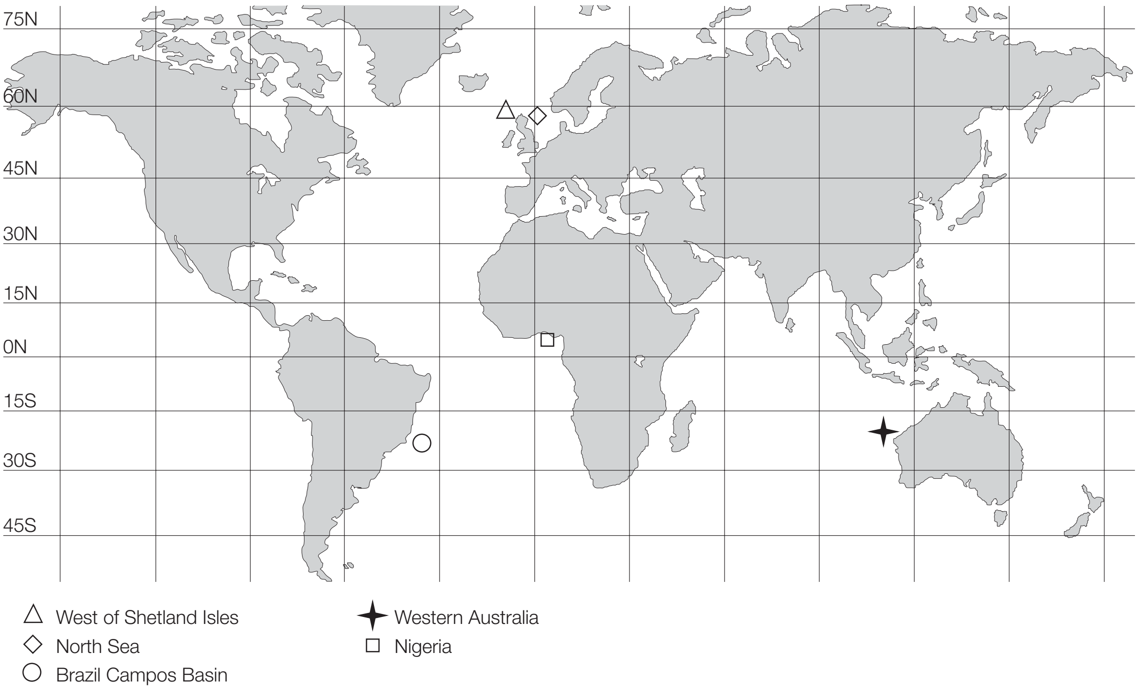


Table 2.3.3 Return periods for scantling requirements and strength assessment

Operational condition	Transit			Normal on-site operation	Inspection/ maintenance	Accidental
	Delivery voyage	Restricted service area	Unrestricted world-wide			
Return period	1 year with all all year data or 10 year with seasonal data	25 years	25 years	100 years	100 years with all-year data or 100 years with seasonal data where consistent with the operation of the unit *see also* 3.4.5	1 year
Environment	World-wide or Owner-defined transit route	Restricted service area	World-wide	Site-specific	Site-specific	Site-specific

3.5 Motions

3.5.1 **General**.

3.5.1.1 The envelope values for unit motions are to be taken at the specific return period specified in Table 2.3.3.

3.5.2 **Roll Motion**.

3.5.2.1 The roll period, T_θ, is to be taken as:

$$T_\theta = \frac{2{,}3\pi\, k_r}{\sqrt{g\, GM}} \text{ seconds}$$

In the event of the roll period being equal to 25 seconds or more, in addition to first-order wave forces, roll excitation by environmental forces including second-order wave forces and dynamic wind gusts are to be considered as applicable. The calculation method is to be acceptable to LR.

3.5.2.2 The roll amplitude, θ, is to be taken as:

$$\theta = \frac{9000\,(1{,}25 - 0{,}025T_\theta)\, f_{bk}}{(B + 75)\,\pi} \text{ degrees}$$

3.5.3 **Pitch motion**.

3.5.3.1 The characteristic pitch period, T_φ, is to be taken as:

$$T_\varphi = \sqrt{\frac{2\pi\,\lambda_\varphi}{g}} \text{ seconds}$$

where

λ_φ = $0{,}6\,(1 + f_T)\,L$

3.5.3.2 The pitch amplitude, φ, is to be taken as:

$$\varphi = 1350\, L^{-0{,}94}\,[1 + F_n^{1{,}2}] \text{ degrees}$$

where

F_n = is the non-dimensional Froude number and is defined as:

$$F_n = \frac{0{,}514V}{\sqrt{g\, L_{wl}}}$$

where

V = is the vessel speed, in knots
= zero at fixed locations
= maximum transit speed for transit condition, *see also* Ch 1,1.3

L_{wl} = is the length on the waterline at the load case draught, in metres.

3.6 Accelerations

3.6.1 **General**.

3.6.1.1 The envelope values for combined translational accelerations due to motion in six degrees of freedom are given. The transverse and longitudinal components of acceleration include the component of gravity due to roll and pitch.

3.6.2 **Common acceleration parameter**.

3.6.2.1 The common acceleration parameter, a_0, is to be taken as:

$$a_0 = (1{,}58 - 0{,}47C_b)\left(\frac{2{,}4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

3.6.3 **Vertical acceleration**.

3.6.3.1 The envelope vertical acceleration, a_v, at any position, is to be taken as:

$$a_v = f_{prob}\, f_{Env\text{-}av} \sqrt{a_{heave}^2 + a_{pitch\text{-}z}^2 + a_{roll\text{-}z}^2} \quad \text{m/s}^2$$

3.6.4 **Transverse acceleration**.

3.6.4.1 The envelope transverse acceleration, a_t, at any position, is to be taken as:

$$a_t = f_{prob}\, f_{Env\text{-}at} \sqrt{a_{sway}^2 + (g \sin\theta + a_{roll\text{-}y})^2} \quad \text{m/s}^2$$

3.6.5 **Longitudinal acceleration**.

3.6.5.1 The envelope longitudinal acceleration, a_{lng}, at any position, is to be taken as:

$$a_{lng} = 0{,}7 f_{prob}\, f_{Env\text{-}alng} \sqrt{a_{surge}^2 + \left(\frac{L}{325}\,(g \sin\varphi + a_{pitch\text{-}x})\right)^2} \quad \text{m/s}^2$$

3.7 Dynamic hull girder loads

3.7.1 **Vertical and horizontal wave bending moments**.

3.7.1.1 The envelope hogging vertical wave bending moment, $M_{wv\text{-}hog}$, and sagging vertical wave bending moment, $M_{wv\text{-}sag}$, and horizontal wave bending moment, $M_{wv\text{-}h}$, are to be taken as:

- Vertical wave bending moment

$$M_{wv\text{-}hog} = f_{prob}\, f_{Env\text{-}Mwv}\, 0{,}19 f_{wv\text{-}v}\, C_{wv}\, L^2\, B\, C_b \quad \text{kNm}$$

$$M_{wv\text{-}sag} = -f_{prob}\, f_{Env\text{-}Mwv}\, 0{,}11 f_{wv\text{-}v}\, C_{wv}\, L^2\, B\, (C_b + 0{,}7) \quad \text{kNm}$$

- Horizontal wave bending moment

$$M_{wv\text{-}h} = f_{prob}\, f_{Env\text{-}Mwv\text{-}h} \left(0{,}3 + \frac{L}{2000}\right) f_{wv\text{-}h}\, C_{wv}\, L^2\, T_{LC}\, C_b \quad \text{kNm}$$

where

$f_{wv\text{-}v}$, $f_{wv\text{-}h}$ = distribution factors for vertical and horizontal wave bending moments along the vessel length, to be taken as:
= 0,0 at A.P.
= 1,0 for 0,4L to 0,65L from A.P.
= 0,0 at F.P.
intermediate values to be obtained by linear interpolation, *see* Fig. 2.3.1

f_{prob} = probability factor is defined in 3.4, as appropriate.

3.7.2 **Vertical wave shear force**.

3.7.2.1 The envelope positive and negative vertical wave shear forces, $Q_{wv\text{-}pos}$ and $Q_{wv\text{-}neg}$, are to be taken as:

$$Q_{wv\text{-}pos} = 0{,}3 f_{prob}\, f_{Env\text{-}Qwv}\, f_{qwv\text{-}pos}\, C_{wv}\, L\, B\, (C_b + 0{,}7) \quad \text{kN}$$

$$Q_{wv\text{-}neg} = -0{,}3 f_{prob}\, f_{Env\text{-}Qwv}\, f_{qwv\text{-}neg}\, C_{wv}\, L\, B\, (C_b + 0{,}7) \quad \text{kN}$$

where

$f_{qwv\text{-}pos}$ = distribution factor for positive vertical wave shear force along the vessel length and is to be taken as:
= 0,0 at A.P.
$= 1{,}59 \dfrac{C_b}{(C_b + 0{,}7)}$ for 0,2L to 0,3L from A.P.
= 0,7 for 0,4L to 0,6L from A.P.
= 1,0 for 0,7L to 0,85L from A.P.
= 0,0 at F.P.

$f_{qwv\text{-}neg}$ = distribution factor for negative vertical wave shear force along the vessel length and is to be taken as:
= 0,0 at A.P.
= 0,92 for 0,2L to 0,3L from A.P.
= 0,7 for 0,4L to 0,6L from A.P.
$= 1{,}73 \dfrac{C_b}{(C_b + 0{,}7)}$ for 0,7L to 0,85L from A.P.
= 0,0 at F.P.
intermediate values of $f_{qwv\text{-}pos}$ and $f_{qwv\text{-}neg}$ are to be obtained by linear interpolation, *see* Fig. 2.3.2 and Fig. 2.3.3 respectively.

3.8 Dynamic local loads

3.8.1 **General**.

3.8.1.1 This Section provides the envelope values for dynamic wave pressure, dynamic tank pressure, green sea load and dynamic deck loads.

3.8.1.2 The envelope dynamic wave pressures are given in 3.8.2.1.

3.8.1.3 The envelope green sea load given in 3.8.3 only applies to scantling requirements and strength assessment.

3.8.1.4 The envelope dynamic tank pressure is a combination of the inertial components due to vertical, transverse and longitudinal acceleration. The envelope dynamic tank pressure components are given in 3.8.4.

3.8.1.5 The envelope dynamic deck loads are given in 3.8.5 and 3.8.6.

3.8.2 **Dynamic wave pressure**.

3.8.2.1 The envelope dynamic wave pressure, $P_{ex\text{-}dyn}$, is to be taken as the greater of the following:

$$P_1 = 2 f_{prob}\, f_{Env\text{-}Pex\text{-}dyn}\, f_{nl\text{-}P1} \left[\left(P_{11} + \frac{135 B_{local}}{4\,(B + 75)} - 1{,}2\,(T_{LC} - z)\right) f_1 + \frac{135 B_{local}}{4\,(B + 75)}\, f_2\right] \quad \text{kN/m}^2$$

$$P_2 = 26 f_{prob}\, f_{Env\text{-}Pex\text{-}dyn}\, f_{nl\text{-}P2} \left[\left(\frac{B_{local}}{8}\,\theta\left(\frac{\pi}{180}\right) + f_T\, C_b\, \frac{0{,}25 B_{local} + 0{,}8 C_{wv}}{14}\left(0{,}7 + \frac{2z}{T_{LC}}\right)\right) f_1 + \left(\frac{B_{local}}{8}\,\theta\left(\frac{\pi}{180}\right) + f_T\, C_b\, \frac{0{,}25 B_{local}}{14}\left(0{,}7 + \frac{2z}{T_{LC}}\right)\right) f_2\right] \quad \text{kN/m}^2$$

where

B_{local} = local breadth at the waterline, for considered draught, not to be taken less than 0,5B, in metres

P_{11} = $(3 f_{s1} + 0{,}8)\, C_{wv}$

f_1 = $f_{lng} - f_{lng}\, f_2 + f_2$

f_2 = $0{,}25 \left(\dfrac{4|y|}{B_{local}} - 1\right)$ for $|y| < 0{,}25 B_{local}$

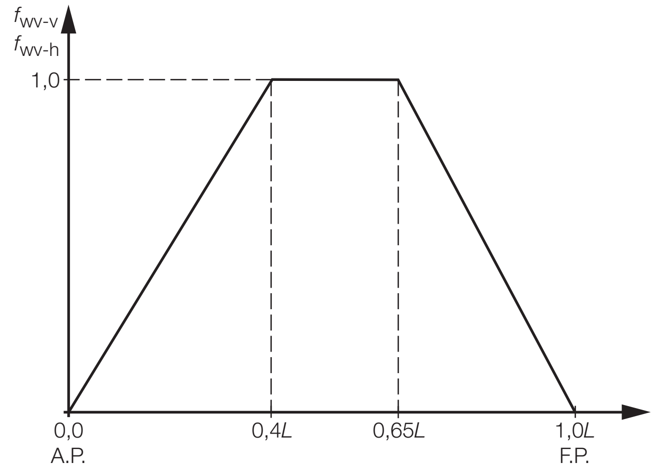


Fig. 2.3.1
Vertical and horizontal wave bending moment distribution for scantling requirements and strength assessment

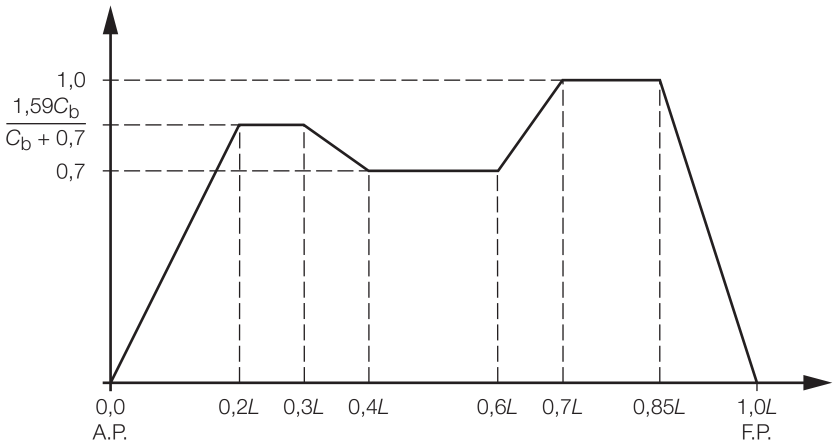


Fig. 2.3.2 Positive vertical wave shear force distribution

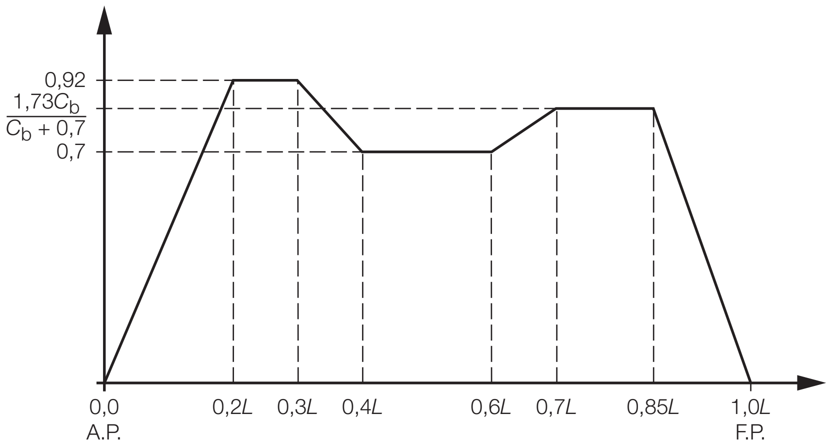


Fig. 2.3.3 Negative vertical wave shear force distribution

$= \dfrac{4|y|}{B_{local}} - 1$ for $|y| \geq 0{,}25B_{local}$

f_{s1} = $C_b + \dfrac{1{,}33}{\sqrt{C_b}}$ at, and aft of, A.P.

= C_b between 0,2L and 0,7L from A.P.

= $C_b + \dfrac{1{,}33}{C_b}$ at, and forward of, F.P.

intermediate values to be obtained by linear interpolation

f_{lng} = 1,0 at, and aft of, A.P.
= 0,7 for 0,2L to 0,7L from A.P.
= 1,0 at, and forward of, F.P.
intermediate values to be obtained by linear interpolation

$f_{nl\text{-}P1}$, $f_{nl\text{-}P2}$ and f_{prob} are given in 3.8.2.2 for scantling requirements and strength assessment application.

3.8.2.2 For scantling requirements and strength assessment, the envelope maximum dynamic wave pressure, $P_{ex\text{-}max}$, *see* Fig. 2.3.4, and minimum dynamic wave pressure, $P_{ex\text{-}min}$, *see* Fig. 2.3.5, are to be taken as:

$P_{ex\text{-}max}$ = $P_{ex\text{-}dyn}$ kN/m^2 below still waterline

= $P_{WL} - 10\,(z - T_{LC})$ kN/m^2
for $T_{LC} < z \leq T_{LC} + \dfrac{P_{WL}}{10}$

= 0 kN/m^2 for $z > T_{LC} + \dfrac{P_{WL}}{10}$

$P_{ex\text{-}min}$ = $- P_{ex\text{-}dyn}$ kN/m^2 below still waterline
= 0 kN/m^2 above still waterline

$P_{ex\text{-}min}$ is not to be taken as less than $-\rho_{sw}\, g\,(T_{LC} - z)$

where

$P_{ex\text{-}dyn}$ = envelope dynamic wave pressure, in kN/m^2, as defined in 3.8.2.1 with:
f_{prob} is defined in 3.4
$f_{nl\text{-}P1} = 1 - 0{,}2\,(f_{prob} - 0{,}5)$
but is not to be taken greater than 1,0
$f_{nl\text{-}P2} = f_\beta\,(1 - 0{,}375\,(f_{prob} - 0{,}5))$
but is not to be taken greater than 1,0

f_β = heading correction factor, *see* 6.3.1.2

P_{WL} = pressure at waterline, to be taken as $P_{ex\text{-}dyn}$ at still waterline, in kN/m^2.

3.8.3 **Green sea load**.

3.8.3.1 The envelope green sea load on the weather deck, P_{wdk}, is to be taken as the greater of the following:

$P_{wdk} = f_{1\text{-}dk}\,(f_{op}\,P_{1\text{-}WL} - 10z_{dk\text{-}T})$ kN/m^2
$P_{wdk} = 0{,}8f_{2\text{-}dk}\,(P_{2\text{-}WL} - 10z_{dk\text{-}T})$ kN/m^2
$P_{wdk} = 34{,}3$ kN/m^2

where

$f_{1\text{-}dk} = 0{,}8 + \dfrac{L}{750}$

$f_{2\text{-}dk} = 0{,}5 + \dfrac{|y|}{B_{wdk}}$

f_{op} = 1,0
at, and forward of, 0,2L from A.P.
= 0,8
at, and aft of, A.P.
intermediate values to be obtained by linear interpolation

$P_{1\text{-}WL}$ = P_1 pressure at still waterline for considered draught, in kN/m^2, *see* 3.8.2.1

$P_{2\text{-}WL}$ = P_2 pressure at still waterline for considered draught, in kN/m^2, *see* 3.8.2.1

$z_{dk\text{-}T}$ = distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in metres

B_{wdk} = local breadth at the weather deck, in metres

Where loads are available from a model test, they may be used for design purposes.

3.8.4 **Dynamic tank pressure**.

3.8.4.1 The envelope dynamic tank pressure, $P_{in\text{-}v}$, due to vertical tank acceleration is to be taken as:

$P_{in\text{-}v} = \rho\, a_v\,(z_0 - z)$ kN/m^2 for strength assessment and scantling requirements.

3.8.4.2 The envelope dynamic tank pressure, $P_{in\text{-}t}$, due to transverse acceleration is to be taken as:

$P_{in\text{-}t} = f_{ull\text{-}t}\,\rho\, a_t\,(y_0 - y)$ kN/m^2 for strength assessment and scantling requirements

where

$f_{ull\text{-}t}$ = factor to account for ullage in cargo tanks, and is to be taken as:
= 0,67 for cargo tanks, including cargo tanks designed for filling with water ballast
= 1,0 for ballast and other tanks.

3.8.4.3 The envelope dynamic tank pressure, $P_{in\text{-}lng}$, due to longitudinal acceleration is to be taken as:

$P_{in\text{-}lng} = f_{ull\text{-}lng}\,\rho\, a_{lng}\,(x_0 - x)$ kN/m^2 for scantling requirements and strength assessment

where

$f_{ull\text{-}lng}$ = factor to account for ullage in cargo tanks, and is to be taken as:
= 0,62 for cargo tanks, including cargo tanks designed for filling with water ballast
= 1,0 for ballast and other tanks.

3.8.4.4 For scantling requirements and strength assessment, the simultaneous acting dynamic tank pressure, $P_{in\text{-}dyn}$, is to be taken as the summation of the components for the considered dynamic load case, *see* 6.3.6.

3.8.5 **Dynamic deck pressure from distributed loading**.

3.8.5.1 The envelope dynamic deck pressure, $P_{deck\text{-}dyn}$, on decks, inner bottom and hatch covers is to be taken as:

$P_{deck\text{-}dyn} = P_{deck}\,\dfrac{a_v}{g}$ kN/m^2

where

P_{deck} = uniformly distributed pressure on lower decks and decks within superstructure, in kN/m^2, as defined in 2.3.2.1.

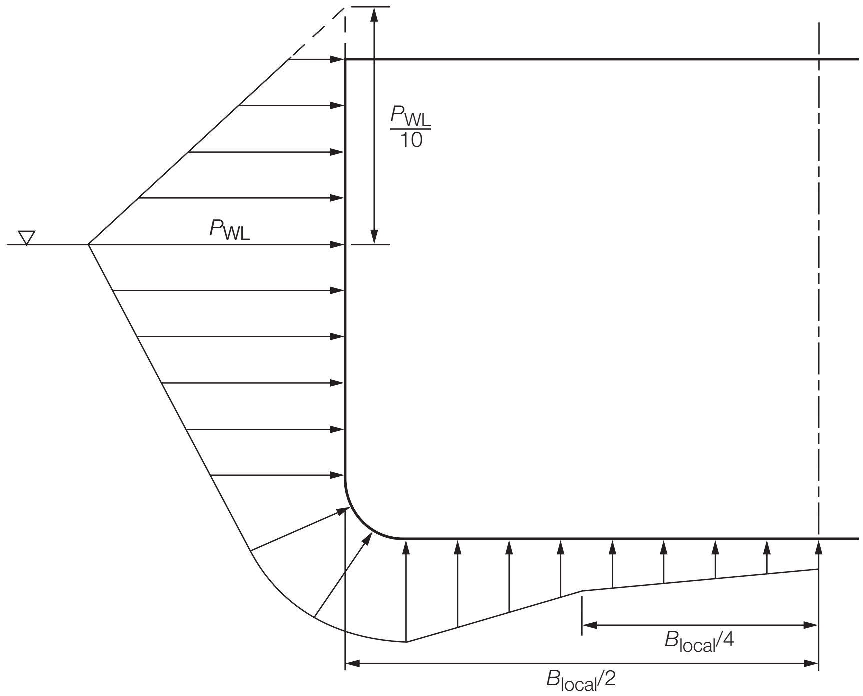


Fig. 2.3.4
Transverse distribution of maximum dynamic wave pressure for scantling requirements and strength assessment

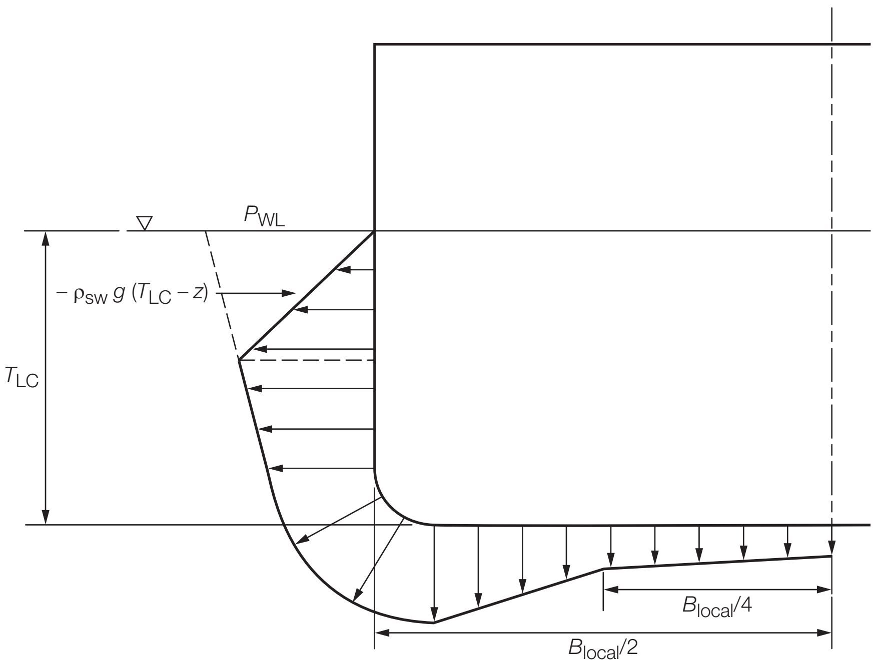


Fig. 2.3.5
Transverse distribution of minimum dynamic wave pressure for scantling requirements and strength assessment

3.8.6 **Dynamic loads from heavy units**.

3.8.6.1 The envelope dynamic deck loads, F_v, F_t, F_{lng}, acting vertically, transversely and longitudinally on supporting structures and securing systems for heavy units of cargo, equipment or structural components are to be taken as:

$F_v = m_{un}\, a_v$ kN

$F_t = m_{un}\, a_t$ kN

$F_{lng} = m_{un}\, a_{lng}$ kN

where

m_{un} = mass of unit, in tonnes.

Section 4
Sloshing and impact loads

4.1 Sloshing loads

4.1.1 **Application**.

4.1.1.1 When the partial filling of tanks is contemplated in operating conditions, the sloshing loads on tank boundaries are to be assessed in accordance with the LR ShipRight Procedure for Ship Units. Full account is to be taken of the operating requirements on station with regard to the filling, transfer and export operations for cargo bulk storage tanks.

4.2 Bottom slamming loads

4.2.1 **Application and limitations**.

4.2.1.1 The slamming loads in this Section apply to units with $C_b \geq 0{,}7$ and bottom slamming draught $\geq 0{,}01L$ and $\leq 0{,}045L$. For operation at deeper draughts, the slamming loads will need to be specially considered.

4.2.1.2 For units with unconventional bow shapes or for harsh service, the slamming loads, green sea loads and bow impact loads are to be determined by a site-specific analysis. The analysis results are to be verified by model tests.

4.2.2 **Slamming pressure**.

4.2.2.1 The bottom slamming pressure, P_{slm}, is to be taken as the greater of:

$P_{slm\text{-}mt} = f_{slm}\, f_{Env\text{-}Pex\text{-}dyn}\, 130g\, c_{slm\text{-}mt}\, e^{c_1}$ kN/m² for empty tanks

$P_{slm\text{-}full} = f_{slm}\, f_{Env\text{-}Pex\text{-}dyn}\, 130g\, c_{slm\text{-}full}\, e^{c_1} - c_{av}\, \rho\, g\, z_{ball}$ kN/m² for full tanks

where

g = acceleration due to gravity, 9,81 m/s²

f_{slm} = longitudinal slamming distribution factor, *see* Fig. 2.4.1
 = 0,0 at 0,5L
 = 1,0 at $[0{,}175 - 0{,}5\,(C_{bl} - 0{,}7)]\,L$ from F.P.
 = 1,0 at $[0{,}1 - 0{,}5\,(C_{bl} - 0{,}7)]\,L$ from F.P.
 = 0,5 at, and forward of, F.P.
 intermediate values to be obtained by linear interpolation

$f_{Env\text{-}Pex\text{-}dyn}$ = environmental factor due to dynamic wave pressure. For the initial design of units to be taken as that derived for the light load draught in Table 2.3.2

C_{bl} = block coefficient, C_b, as defined in 3.1, but not to be taken less than 0,7 or greater than 0,8

 = slamming coefficient for empty tanks

$c_{slm\text{-}mt} = 5{,}95 - 10{,}5\left(\dfrac{T_{FP\text{-}mt}}{L}\right)^{0{,}2}$

 = slamming coefficient for full tanks

$c_{slm\text{-}full} = 5{,}95 - 10{,}5\left(\dfrac{T_{FP\text{-}full}}{L}\right)^{0{,}2}$

c_1 = 0,0 for $L \leq 180$ m
 = $-0{,}0125\,(L - 180)^{0{,}705}$ for $L > 180$ m

$T_{FP\text{-}mt}$ = design slamming light load draught at F.P. with tanks within the bottom slamming region empty, as defined in 4.2.2.3, in metres

$T_{FP\text{-}full}$ = design slamming light load draught at F.P. with tanks within the bottom slamming region full, as defined in 4.2.2.4, in metres

c_{av} = dynamic load coefficient, to be taken as 1,25

L = Rule length, in metres

z_{ball} = vertical distance from tank top to load point, in metres.

4.2.2.2 The designer is to provide the design slamming draughts $T_{FP\text{-}mt}$ and $T_{FP\text{-}full}$.

4.2.2.3 The design slamming draught at the F.P., $T_{FP\text{-}mt}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for all transit conditions wherein the tanks within the bottom slamming region are empty.

4.2.2.4 The design slamming draught at the F.P., $T_{FP\text{-}full}$, is not to be greater than the minimum draught at the F.P. indicated in the loading manual for any transit conditions wherein the tanks within the bottom slamming region are full.

4.2.2.5 The loading guidance information is to indicate clearly the design slamming draught.

4.3 Bow impact loads

4.3.1 **Application and limitations**.

4.3.1.1 The bow impact pressure applies to the side structure in the area forward of 0,1L aft of F.P. and between the waterline at draught T_{LT} and the highest deck at side.

4.3.2 **Bow impact pressure**.

4.3.2.1 The bow impact pressure, P_{im}, is to be taken as:

$P_{im} = 1{,}025 f_{im}\, f_{Env\text{-}Pex\text{-}dyn}\, c_{im}\, V_{im}^2 \sin\gamma_{wl}$ kN/m²

where

f_{im} = 0,55 at 0,1L aft of F.P.
 = 0,9 at 0,0125L aft of F.P.
 = 1,0 at, and forward of, F.P.
 intermediate values to be obtained by linear interpolation

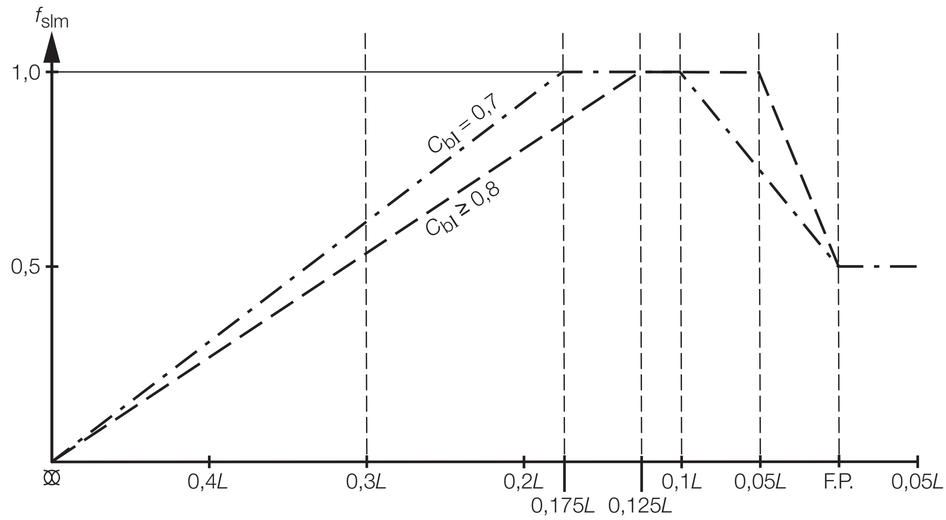


Fig. 2.4.1 Longitudinal distribution of slamming pressure

$f_{Env\text{-}Pex\text{-}dyn}$ = environmental factor due to dynamic wave pressure
For the initial design of units to be taken as:
$f_{Env\text{-}Pex\text{-}dyn}$ for the T_{LT} in Table 2.3.2 for the pressure calculation at the light load waterline
$f_{EnvPex\text{-}dyn}$ for the T_{sc} in Table 2.3.2 for the pressure calculation at and above the deep load waterline
For the pressure calculation in between T_{LT} and T_{sc}, the factor is be obtained by interpolating between the $f_{Env\text{-}Pex\text{-}dyn}$ factors for T_{LT} and for T_{sc}

V_{im} = impact speed, in m/s
For fixed locations, impact speed to be taken as $5 \sin\alpha_{wl} + \sqrt{L}$

α_{wl} = local waterline angle at the position considered, but is not to be taken as less than 35°, *see* Fig. 2.4.2

γ_{wl} = local bow impact angle measured normal to the shell from the horizontal to the tangent line at the position considered, but is not to be less than 50°, *see* Fig. 2.4.2

c_{im} = 1,0
for positions between draughts T_{LT} and T_{sc}

$$= \sqrt{1 + \cos^2\left[\frac{90\,(h_{fb} - 2h_o)}{h_{fb}}\right]}$$

for positions above draught T_{sc}

h_{fb} = vertical distance from the waterline at draught T_{sc} to the highest deck at side, *see* Fig. 2.4.2, in metres

h_o = vertical distance from the waterline at draught T_{sc} to the position considered, *see* Fig. 2.4.2, in metres

L = Rule length, in metres

T_{sc} = scantling draught, in metres

T_{LT} = minimum design light draught, in metres

W_{Lj} = waterline at the position considered, *see* Fig. 2.4.2

NOTE

Where local bow impact angle measured normal to the shell, γ_{wl}, is not available, this angle may be taken as:

$$\gamma_{wl} = \tan^{-1}\left(\frac{\tan\beta_{pl}}{\cos\alpha_{wl}}\right)$$

where

β_{pl} = local body plan angle at the position considered from the horizontal to the tangent line, but is not to be less than 35°.

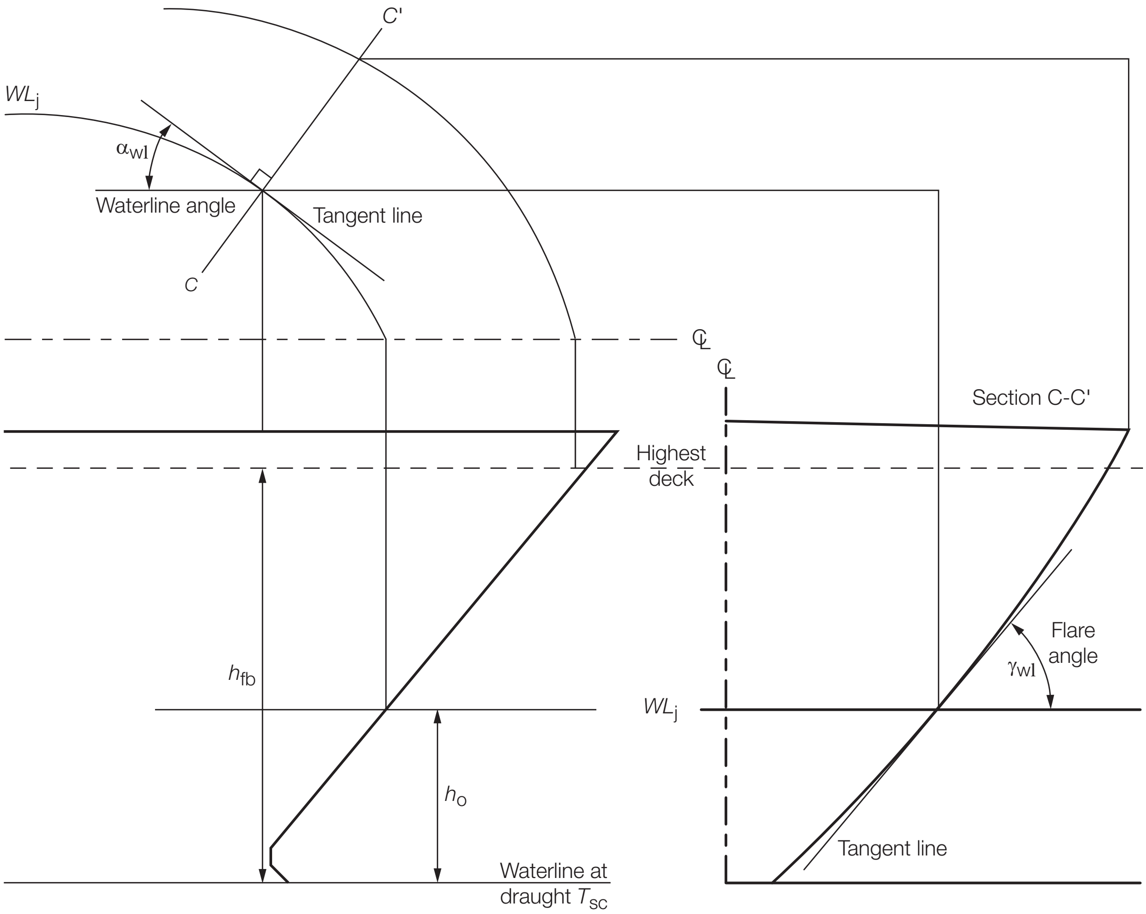


Fig. 2.4.2 Definition of bow geometry

■ *Section 5*

Accidental loads

5.1 Flooded condition

5.1.1 **Global loads.**

5.1.1.1 The still water bending moments and the still water shear forces in flooded condition are to be determined for each flooding scenario, considering the damaged compartments flooded up to the equilibrium waterline.

5.1.2 **Local pressure.**

5.1.2.1 The pressure in compartments and tanks in flooded condition or damaged condition is to be taken as $P_{in\text{-}flood}$, *see* 2.3.2.1.

5.1.3 **Assessment.**

5.1.3.1 Flooding strength calculations are to be carried out to determine the effects of accidental flooding on the hull strength. Flooding calculations are to be undertaken for all flooding scenarios required by National Regulations. When considering the static and dynamic loads acting simultaneously (S+D), credit may be given to agreed documented mitigation measures where permitted by the National Regulations.

5.2 Blast condition

5.2.1 **Global loads.**

5.2.1.1 The blast condition is to be assessed for the following load combinations of blast pressure and global loads:

(a) Blast pressure + Permissible still water hogging bending moment for the operational condition.

(b) Blast pressure + Permissible still water sagging bending moment for the operational condition. Loading conditions where there is no risk of blast loads need not be included in the calculation of the permissible still water bending moments for the blast assessment.

Environmental loads need not be considered. *See also* Pt 4, Ch 3,4.16.

5.2.2 **Pressure**.

5.2.2.1 Generally, the blast pressure is a rapidly propagating pressure or shock-wave in the atmosphere, with high pressure, high density and high particle velocity.

5.2.2.2 The design blast pressures are to be defined by the Owners/designers and are to comply with National Regulations.

5.2.2.3 Design calculations are to be submitted which may be based on elastic analysis or elastoplastic design methods.

5.2.3 **Assessment**.

5.2.3.1 Assessment of the potential fire loadings and blast pressures are to be based on the specific hazards associated with the general layout of the unit, production and process activities and operational constraints. For assessment of the post accident condition, the static loads may be reduced if damage control or recovery measures are implemented, *see* Pt 4, Ch 3,4.3.1.

5.2.3.2 The blast load case is applicable primarily to the upper deck, deck-house and turret boundary. The pressures acting on the opposite side of these structures to the blast load (ballast water pressure, inert gas pressure, etc.) may be ignored when assessing the local scantlings but the hull girder stresses (due to shear and bending) are to be included. The amount of damage to the structure following a blast is to be considered in the assessment.

5.2.4 **Boundary bulkheads and main decks**.

5.2.4.1 Particular consideration is to be given to the potential effects of fire and blast impinging on exposed boundary bulkheads of accommodation spaces and main decks. Where boundary bulkheads and main decks can be subjected to blast loading, the scantlings are to comply with Pt 4, Ch 3,4.16.9.

5.3 Collision loads

5.3.1 **General**.

5.3.1.1 Collision loads are to be considered in the design of the unit as applicable to the function of the unit. In general, the loads described in Pt 4, Ch 3 are to be considered.

■ *Section 6*
Combination of loads

6.1 Symbols

6.1.1 For the purposes of this Section, the following symbols apply:

$M_{v\text{-}total}$ = design vertical bending moment, in kNm

$M_{sw\text{-}perm\text{-}maint}$ = permissible hull girder hogging and sagging still water bending moment envelopes for inspection/maintenance condition, in kNm, *see* 2.1 and Table 2.6.1

$M_{sw\text{-}perm\text{-}sea}$ = permissible hull girder hogging and sagging still water bending moment envelopes for transit condition, in kNm, *see* 2.1 and Table 2.6.1

$M_{sw\text{-}perm\text{-}oper}$ = permissible hull girder hogging and sagging still water bending moment envelopes for operational condition, in kNm, *see* 2.1 and Table 2.6.1

$M_{sw\text{-}perm\text{-}flood}$ = permissible hull girder hogging and sagging still water bending moment envelopes for flooded condition, in kNm, *see* Table 2.6.1

M_{wv} = vertical wave bending moment for a considered dynamic load case, in kNm, *see* 6.3.2.1

$M_{h\text{-}total}$ = design horizontal bending moment, in kNm

M_h = horizontal wave bending moment for a considered dynamic load case, in kNm, *see* 6.3.2.1

$M_{wv\text{-}hog}$ = hogging vertical wave bending moment, in kNm, *see* 3.7.1.1

$M_{wv\text{-}sag}$ = sagging vertical wave bending moment, in kNm, *see* 3.7.1.1

$M_{wv\text{-}h}$ = horizontal wave bending moment, in kNm, *see* 3.7.1.1

Q = design vertical shear force, in kN

$Q_{sw\text{-}perm\text{-}maint}$ = permissible hull girder positive and negative still water shear force limits for inspection/maintenance condition, in kN, *see* 2.1 and Table 2.6.1

$Q_{sw\text{-}perm\text{-}sea}$ = permissible hull girder positive and negative still water shear force limits for transit condition, in kN, *see* 2.1 and Table 2.6.1

$Q_{sw\text{-}perm\text{-}oper}$ = permissible hull girder positive and negative still water shear force limits for operational condition, in kN, *see* 2.1 and Table 2.6.1

$Q_{sw\text{-}perm\text{-}flood}$ = permissible hull girder positive and negative still water shear force envelopes for flood condition, in kN, *see* Table 2.6.1

Q_{wv} = vertical wave shear force for a considered dynamic load case, in kN, *see* 6.3.2.1

$Q_{wv\text{-}pos}$ = envelope positive vertical wave shear force, in kN, as defined in 3.7.2.1

$Q_{wv\text{-}neg}$ = envelope negative vertical wave shear force, in kN, as defined in 3.7.2.1

f_{mv} = dynamic load combination factor for vertical wave bending moment for considered dynamic load case, as defined in 6.3.2.1

f_{qv} = dynamic load combination factor for vertical wave shear force for considered dynamic load case, as defined in 6.3.3.1

f_β = heading correction factor, as defined in 6.3.1.2

P_{ex} = design sea pressure, in kN/m^2

Table 2.6.1 Design load combinations

Global hull girder loads								
Load component	Operation on-site		Inspection/maintenance		Transit		Flooded	
	S	S+D	S	S+D	S	S+D	S	S+D
$M_{v\text{-total}}$	$M_{sw\text{-perm-oper}}$	$M_{sw\text{-perm-oper}} + M_{wv}$	$M_{sw\text{-perm-maint}}$	$M_{sw\text{-perm-maint}} + M_{wv}$	$M_{sw\text{-perm-sea}}$	$M_{sw\text{-perm-sea}} + M_{wv}$	$M_{sw\text{-perm-flood}}$	$M_{sw\text{-perm-flood}} + M_{wv}$
$M_{h\text{-total}}$	–	M_h	–	M_h	–	M_h	–	M_h
Q	$Q_{sw\text{-perm-oper}}$	$Q_{sw\text{-perm-oper}} + Q_{wv}$	$Q_{sw\text{-perm-maint}}$	$Q_{sw\text{-perm-maint}} + Q_{wv}$	$Q_{sw\text{-perm-sea}}$	$Q_{sw\text{-perm-sea}} + Q_{wv}$	$Q_{sw\text{-perm-flood}}$	$Q_{sw\text{-perm-flood}} + Q_{wv}$

Local loads										
Load component		Space type	Operation on-site		Inspection/maintenance		Transit		Flooded	
			S	S+D	S	S+D	S	S+D	S	S+D
External sea pressure	P_{ex}	Exposed deck		P_{wdk_dyn}		$P_{wdk\text{-dyn}}$		$P_{wdk\text{-dyn}}$		$\max(P_{hys} + P_{ex\text{-dyn}}, P_{wdk\text{-dyn}})$
		Hull envelope	P_{hys}	$P_{hys} + P_{wv\text{-dyn}}$	P_{hys}	$P_{hys} + P_{wv\text{-dyn}}$	P_{hys}	$P_{hys} + P_{wv\text{-dyn}}$	P_{hys}	$P_{hys} + P_{wv\text{-dyn}}$
Liquid pressure	P_{in}	Ballast tanks	$P_{in\text{-air}} + P_{drop}$	$P_{in\text{-tk}} + P_{in\text{-dyn}}$	$P_{in\text{-test}}$	$P_{in\text{-test}} + P_{in\text{-dyn}}$	$P_{in\text{-air}} + P_{drop}$	$P_{in\text{-tk}} + P_{in\text{-dyn}}$	$P_{in\text{-flood}}$	$\max(P_{in\text{-tk}}, P_{in\text{-flood}}) + P_{in\text{-dyn}}$
		Cargo tanks/ other tanks designed for liquid filling	$P_{in\text{-tk}} + P_{valve}$	$P_{in\text{-tk}} + P_{in\text{-dyn}}$	$\max(P_{in\text{-tk}} + P_{valve}, P_{in\text{-test}})$	$P_{in\text{-test}} + P_{in\text{-dyn}}$	$P_{in\text{-tk}} + P_{valve}$	$P_{in\text{-tk}} + P_{in\text{-dyn}}$	$P_{in\text{-flood}}$	$\max(P_{in\text{-tk}}, P_{in\text{-flood}}) + P_{in\text{-dyn}}$
		Fresh water and fuel/lube oil tanks	$P_{in\text{-air}}$	$P_{in\text{-tk}} + P_{in\text{-dyn}}$	$P_{in\text{-test}}$	$P_{in\text{-test}} + P_{in\text{-dyn}}$	$P_{in\text{-air}}$	$P_{in\text{-tk}} + P_{in\text{-dyn}}$	$P_{in\text{-flood}}$	$\max(P_{in\text{-tk}}, P_{in\text{-flood}}) + P_{in\text{-dyn}}$
		Water tight boundaries/ void spaces			$P_{in\text{-test}}$	$P_{in\text{-test}} + P_{in\text{-dyn}}$			$P_{in\text{-flood}}$	$\max(P_{in\text{-tk}}, P_{in\text{-flood}}) + P_{in\text{-dyn}}$
		Dry space							$P_{in\text{-flood}}$	$P_{in\text{-flood}} + P_{in\text{-dyn}}$
Deck loads	P_{dk}	Dry space	P_{stat}	$P_{stat} + P_{dk\text{-dyn}}$	P_{stat}	$P_{stat} + P_{dk\text{-dyn}}$	P_{stat}	$P_{stat} + P_{dk\text{-dyn}}$	P_{stat}	$P_{stat} + P_{dk\text{-dyn}}$

NOTES
1. All the dynamic wave loads are to be adjusted by the f_{prob} factor. The value of f_{prob} is dependent on the operational condition, *see* 3.4.
2. The pressure in cargo tanks, and other tanks designed for liquid filling, that are stated in the unit's Operations Manual as not to be loaded during transit may be taken as zero for the transit assessment.

P_{hys} = static sea pressure at considered draught, in kN/m^2, as defined in 2.3.2.1
$P_{wv\text{-}dyn}$ = dynamic wave pressure for a considered dynamic load case, in kN/m^2, as defined in 6.3.4.1
$P_{wdk\text{-}dyn}$ = green sea load for a considered dynamic load case, in kN/m^2, as defined in 6.3.5.1
P_{in} = design tank pressure, in kN/m^2
$P_{in\text{-}test}$ = tank testing pressure, in kN/m^2, as defined in Table 2.2.1
$P_{in\text{-}air}$ = static tank pressure in the case of overfilling, in kN/m^2, as defined in Table 2.2.1
P_{drop} = added overpressure due to liquid flow through air pipe or overflow pipe, in kN/m^2, as defined in Table 2.2.1 and Table 2.6.1
P_{valve} = setting of pressure relief valve, in kN/m^2, as defined in Table 2.2.1
$P_{in\text{-}tk}$ = static tank pressure, in kN/m^2, as defined in Table 2.2.1
$P_{in\text{-}dyn}$ = dynamic tank pressure for a considered dynamic load case, in kN/m^2, as defined in 6.3.6.1
$P_{in\text{-}flood}$ = pressure in compartments and tanks in flooded or damaged condition, in kN/m^2, as defined in Table 2.2.1
P_{stat} = static pressure on decks and inner bottom, in kN/m^2, as defined in Table 2.2.1
P_{dk} = design deck pressure, in kN/m^2, as defined in Table 2.2.1
$P_{deck\text{-}dyn}$ = envelope dynamic deck pressure on decks, inner bottom and hatch cover, in kN/m^2, as defined in 3.8.5.1
$P_{dk\text{-}dyn}$ = dynamic deck pressure on decks, inner bottom and hatch covers for a considered dynamic load case, in kN/m^2, as defined in 6.3.7.1
P_{ctr} = dynamic wave pressure at bottom centreline, as defined in 6.3.7.1
= $f_{ctr}\, P_{ex\text{-}max}$ kN/m^2
P_{bilge} = dynamic wave pressure at z = 0 and y = $B_{local}/2$, as defined in 6.3.7.1
= $f_{bilge}\, P_{ex\text{-}max}$ kN/m^2
P_{WL} = dynamic wave pressure at waterline, as defined in 6.3.7.1
= $f_{WL}\, P_{ex\text{-}max}$ kN/m^2
$P_{ex\text{-}max}$ = envelope maximum dynamic wave pressure, in kN/m^2, as defined in 6.3.4.1
$P_{1\text{-}WL}$ = P_1 pressure at still waterline for considered draught, in kN/m^2, *see* 6.3.4.1
$P_{2\text{-}WL}$ = P_2 pressure at still waterline for considered draught, in kN/m^2, *see* 6.3.4.1
F_{stat} = load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN, as defined in 2.3.2.1
$F_{dk\text{-}dyn}$ = dynamic load acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, in kN, as defined in 6.3.7.2
F_v = envelope vertical dynamic load from heavy units, in kN, *see* 3.8.6
f_{WL} = dynamic load combination factor for dynamic wave pressure, P_{WL}, at still waterline for considered dynamic load case, *see* 6.3.4.1
f_{bilge} = dynamic load combination factor for dynamic wave pressure, P_{bilge}, at bilge for considered dynamic load case, *see* 6.3.4.1
f_{ctr} = dynamic load combination factor for dynamic wave pressure, P_{ctr}, at centreline for considered dynamic load case, *see* 6.3.4.1
$f_{1\text{-}dk} = 0{,}8 + \dfrac{L}{750}$ *see* 6.3.5.1
$f_{2\text{-}dk} = 0{,}5 + \dfrac{|y|}{B_{wdk}}$ *see* 6.3.5.1
f_{op} = 1,0 at and forward of 0,2L from A.P.
= 0,8 at and aft of A.P.
intermediate values to be obtained by linear interpolation, *see* 6.3.5.1
f_v = dynamic load combination factor for vertical acceleration for considered dynamic load case. f_v is to be taken as appropriate to the tank location, *see* 6.3.6.1
$f_{v\text{-}mid}$ = dynamic load combination factor for vertical acceleration for considered dynamic load case, *see* 6.3.6.1
f_t = dynamic load combination factor for transverse acceleration for considered dynamic load case, *see* 6.3.6.1
f_{lng} = dynamic load combination factor for longitudinal acceleration for considered dynamic load case. f_{lng} is to be taken as most appropriate dependent on tank location, *see* 6.3.6.1
$z_{dk\text{-}T}$ = distance from the deck to the still waterline at the applicable draught for the loading condition being considered, in metres, *see* 6.3.5.1
L = Rule length, in metres
B_{wdk} = local breadth at the weather deck, in metres, *see* 6.3.4.1
B_{local} = local breadth at waterline for considered draught, in metres, *see* 6.3.4.1
T_{LC} = draught in the loading condition being considered, in metres, *see* 6.3.4.1
x = longitudinal coordinate, in metres
y = transverse coordinate, in metres
z = vertical coordinate, in metres
x_0 = longitudinal coordinate of reference point, in metres
y_0 = transverse coordinate of reference point, in metres
z_0 = vertical coordinate of reference point, in metres
ρ_{sw} = density of sea-water, 1,025 tonnes/m^3
g = acceleration due to gravity, 9,81m/s^2.

6.2 General

6.2.1 **Application**.

6.2.1.1 The design load combinations given in Table 2.6.1 corresponding to the applicable static load scenarios given in 2.3 are to be used as the basis for the scantling requirements and strength assessment (by FEM).

6.2.1.2 For each dynamic load case, the envelope load values as given in Section 3 are multiplied with dynamic load combination factors to give simultaneously acting dynamic loads.

6.2.1.3 The procedures for calculating the simultaneously acting dynamic loads are given in 6.3. The dynamic loads for unrestricted worldwide transit are given in Section 7. The dynamic loads for the site-specific load scenarios are given in Section 8.

6.3 Application of dynamic loads

6.3.1 **Dynamic load combination factors**.

6.3.1.1 For scantling assessment, the dynamic load combination factors used for the calculations of the simultaneously acting dynamic loads are to be taken as given in:

- Section 7 for unrestricted worldwide transit;
- Section 8 for site-specific load scenarios.

For strength assessment by FEM, the dynamic load combination factors are to be taken as given in:

- Section 7 for unrestricted worldwide transit;
- Section 8 for site-specific load scenarios

6.3.1.2 The heading correction factor, f_β, is to be taken as follows:

- For transit conditions using the worldwide environment, as defined in Table 2.3.3:

  f_β = 0,8 for beam sea dynamic load cases

  = 1,0 for all other dynamic load cases
- For all other operational conditions, as defined in Table 2.3.3:

  f_β = 1,0 for beam sea dynamic load cases.

6.3.2 **Vertical and Horizontal wave bending moment for a considered dynamic load case**.

6.3.2.1 The simultaneously acting vertical wave bending moment, M_{wv} and horizontal wave bending moment, M_h, are to be taken as:

- Vertical wave bending moment:

  $M_{wv} = f_\beta f_{mv} M_{wv\text{-}hog}$ kNm for $f_{mv} \geq 0$

  $M_{wv} = -f_\beta f_{mv} M_{wv\text{-}sag}$ kNm for $f_{mv} < 0$
- Horizontal wave bending moment:

  $M_h = f_\beta f_{mh} M_{wv\text{-}h}$ kNm.

6.3.3 **Vertical wave shear force for a considered dynamic load case**.

6.3.3.1 The simultaneously acting vertical wave shear force, Q_{wv}, is to be taken as:

$Q_{wv} = f_\beta f_{qv} Q_{wv\text{-}pos}$ kNm for $f_{qv} \geq 0$

$Q_{wv} = -f_\beta f_{qv} Q_{wv\text{-}neg}$ kNm for $f_{qv} < 0$.

6.3.4 **Dynamic wave pressure distribution for a considered dynamic load case**.

6.3.4.1 The simultaneously acting dynamic wave pressure, $P_{wv\text{-}dyn}$, is to be taken as follows, but not to be less than $-\rho_{sw}\, g\, (T_{LC} - z)$ below still waterline or less than 0 above still waterline:

- For the port and starboard side within the region with a defined bilge:

$$P_{wv\text{-}dyn} = P_{ctr} + \frac{|y|}{0{,}5B_{local}} (P_{bilge} - P_{ctr})$$

between centreline and start of bilge

$$P_{wv\text{-}dyn} = P_{bilge} + \frac{z}{T_{LC}} (P_{WL} - P_{bilge})$$

between end of bilge and still waterline

$$P_{wv\text{-}dyn} = P_{WL} - 10\,(z - T_{LC})$$

for side shell above still waterline

intermediate values of $P_{wv\text{-}dyn}$ around the bilge are to be obtained by linear interpolation along the vertical distance.

- For the port and starboard side within the region without a defined bilge:

$$P_{wv\text{-}dyn} = P_{ctr} + \frac{z}{T_{LC}} (P_{WL} - P_{ctr})$$

between bottom centreline and still waterline

$$P_{wv\text{-}dyn} = P_{WL} - 10\,(z - T_{LC}) \quad \text{above still waterline}$$

where

P_{ctr} = dynamic wave pressure at bottom centreline, to be taken as:

= $f_{ctr} P_{ex\text{-}max}$ kN/m^2

P_{bilge} = dynamic wave pressure at $z = 0$ and $y = B_{local}/2$, to be taken as:

= $f_{bilge} P_{ex\text{-}max}$ kN/m^2

P_{WL} = dynamic wave pressure at waterline, to be taken as:

= $f_{WL} P_{ex\text{-}max}$ kN/m^2.

6.3.4.2 Fig. 2.6.1 to Fig. 2.6.3 illustrate simultaneously acting dynamic wave pressures.

6.3.5 **Green sea load of a considered dynamic load case**.

6.3.5.1 The simultaneously acting green sea load on the weather deck, $P_{wdk\text{-}dyn}$ is shown in Table 2.6.2.

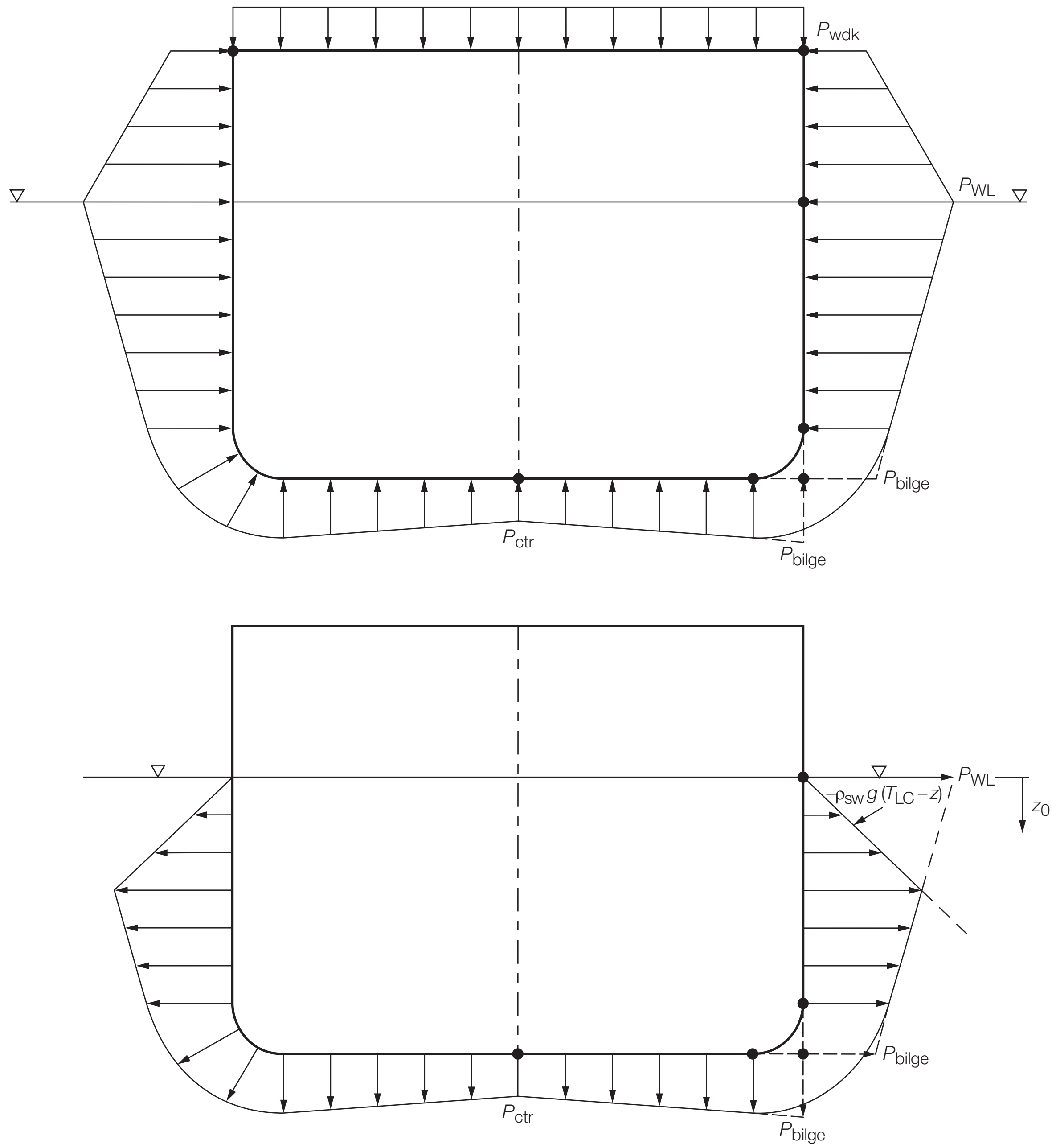


Fig. 2.6.1 Dynamic wave pressure for head sea dynamic load cases

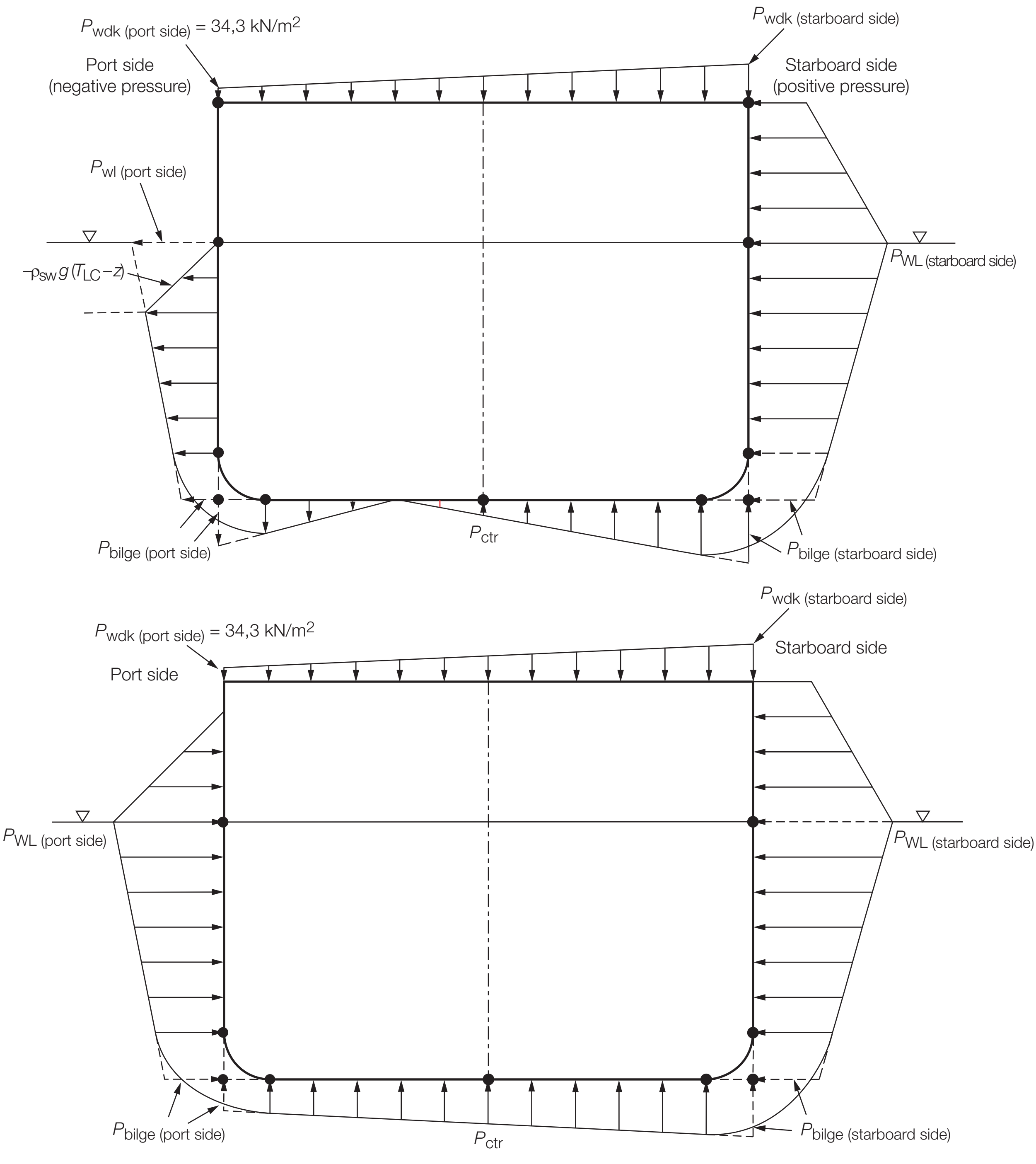


Fig. 2.6.2 Dynamic wave pressure for beam sea dynamic load cases

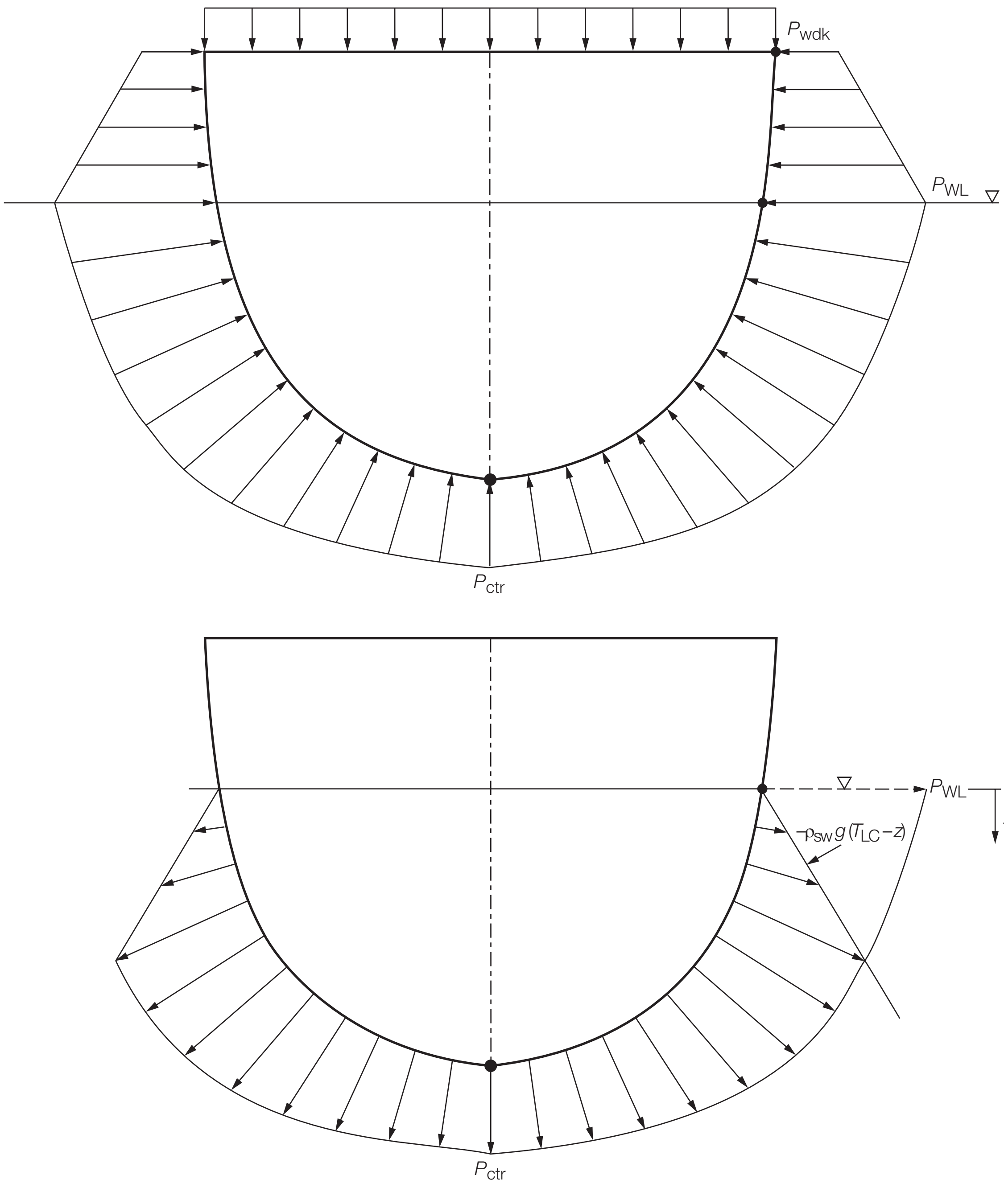


Fig. 2.6.3 Pressure distribution for wave crest and wave trough for forward and aft

Table 2.6.2 Green sea load

Inclined green sea load, *see* Note
$P_{wdk\text{-}dyn}$ = max. ($f_{1\text{-}dk}$ (f_{WL} f_{op} $P_{1\text{–}WL}$ – 10$z_{dk\text{-}T}$), 0,8 (f_{WL} $P_{2\text{-}WL}$ – 10$z_{dk\text{-}T}$), 34,3) kN/m^2
Uniformly distributed
$P_{wdk\text{-}dyn}$ = max. ($f_{1\text{-}dk}$ (f_{WL} f_{op} $P_{1\text{–}WL}$ – 10$z_{dk\text{-}T}$), 0,8 (f_{WL} $P_{2\text{-}WL}$ – 10$z_{dk\text{-}T}$), 34,3) kN/m^2
NOTE Inclined green sea load is obtained by linear interpolation between port side and starboard side, with load decreasing from port side to starboard side, with the maximum value at vessel side given by the formula and the minimum value at the opposite side taken as 34,3 kN/m^2. The assessment is then to be repeated, with loading decreasing from starboard side to port side.

6.3.6 **Dynamic tank pressure for a considered dynamic load case**.

6.3.6.1 The simultaneously acting dynamic tank pressure, $P_{in\text{-}dyn}$, is to be taken as:

- For tanks in the cargo region:

$$P_{in\text{-}dyn} = f_\beta \, (f_v \, P_{in\text{-}v} + f_t \, P_{in\text{-}t} + f_{lng} \, P_{in\text{-}lng}) \ \text{kN/m}^2$$

- For tanks outside the cargo region:

$$P_{in\text{-}dyn} = f_\beta \, (f_{v\text{-}mid} \, P_{in\text{-}v} + | f_t \, P_{in\text{-}t} | + | f_{lng} \, P_{in\text{-}lng} |) \ \text{kN/m}^2$$

where

$P_{in\text{-}v}$ = envelope dynamic tank pressure due to vertical acceleration, as defined in 3.8.4.1 with reference point z_0 taken as:
(a) top of tank
(b) top of air pipe/overflow for ballast tanks designed
see Fig. 2.6.4, in kN/m^2

$P_{in\text{-}t}$ = envelope dynamic tank pressure due to transverse acceleration, as defined in 3.8.4.2 with reference point y_0 taken as:
(a) tank top towards port side for $f_t > 0$
(b) tank top towards starboard side for $f_t < 0$
see Fig. 2.6.5, in kN/m^2

$P_{in\text{-}lng}$ = envelope dynamic tank pressure due to longitudinal acceleration, as defined in 3.8.4.3 with reference point x_0 taken as:
(a) forward bulkhead for $f_{lng} > 0$
(b) aft bulkhead of the tank for $f_{lng} < 0$,
see Fig. 2.6.6, in kN/m^2

NOTES

1. For a non-parallel tank, y_0 should be selected from either forward or aft bulkhead corresponding to the reference point x_0. If the longitudinal load combination factor $f_{lng} = 0$, y_0 should be selected from the bulkhead with the greater breadth.
2. The vertical, transverse and longitudinal acceleration is to be taken at the centre of gravity of the tank under consideration.

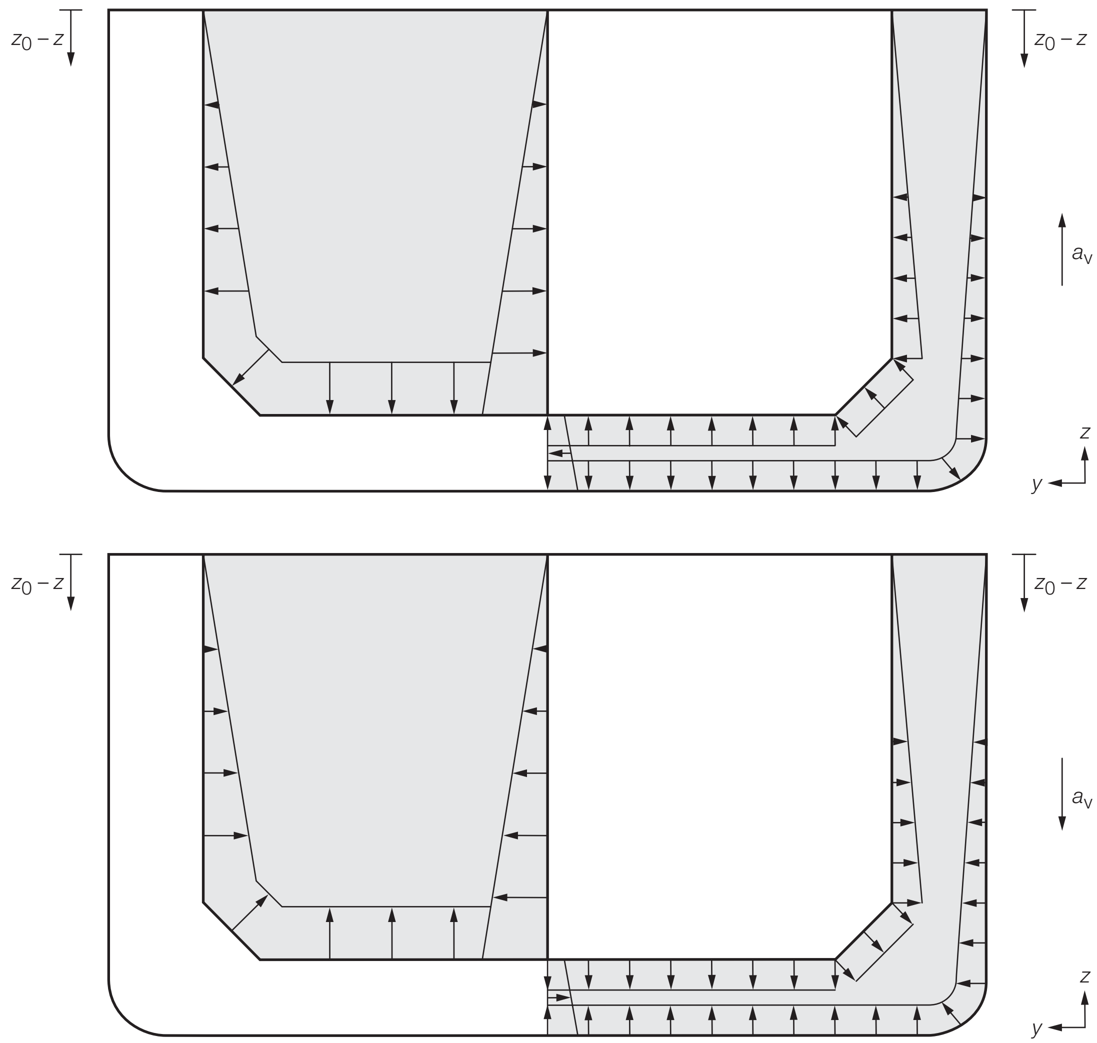


Fig. 2.6.4
Dynamic tank pressure in cargo tank (Left) and ballast tank (Right) due to positive and negative vertical tank acceleration

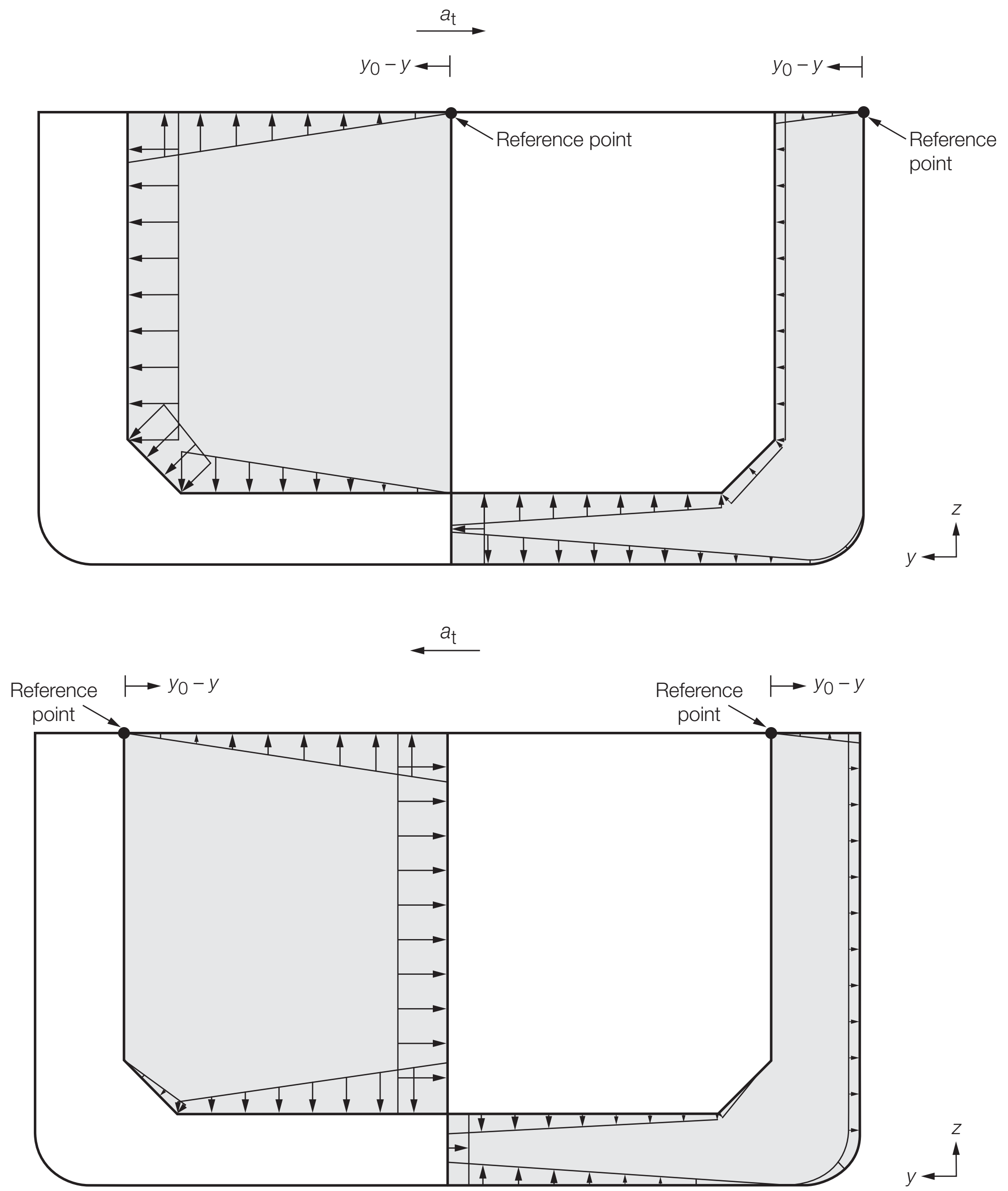


Fig. 2.6.5
Dynamic tank pressure in cargo tank (Left) and ballast tank (Right) due to negative and positive transverse tank acceleration

6.3.7 **Dynamic deck loads for a considered dynamic load case**.

6.3.7.1 The simultaneously acting dynamic deck load for uniformly distributed load, $P_{dk\text{-}dyn}$, on the enclosed upper deck, where a forecastle or poop is fitted, and also on all lower decks, is to be taken as:

$$P_{dk\text{-}dyn} = f_\beta \, f_{v\text{-}mid} \, P_{deck\text{-}dyn} \quad \text{kN/m}^2$$

6.3.7.2 The simultaneously acting dynamic vertical force for heavy units, $F_{dk\text{-}dyn}$, acting on supporting structures and securing systems for heavy units of cargo, equipment or structural components, is to be taken as:

$$F_{dk\text{-}dyn} = f_\beta \, f_{v\text{-}mid} \, F_v \quad \text{kN.}$$

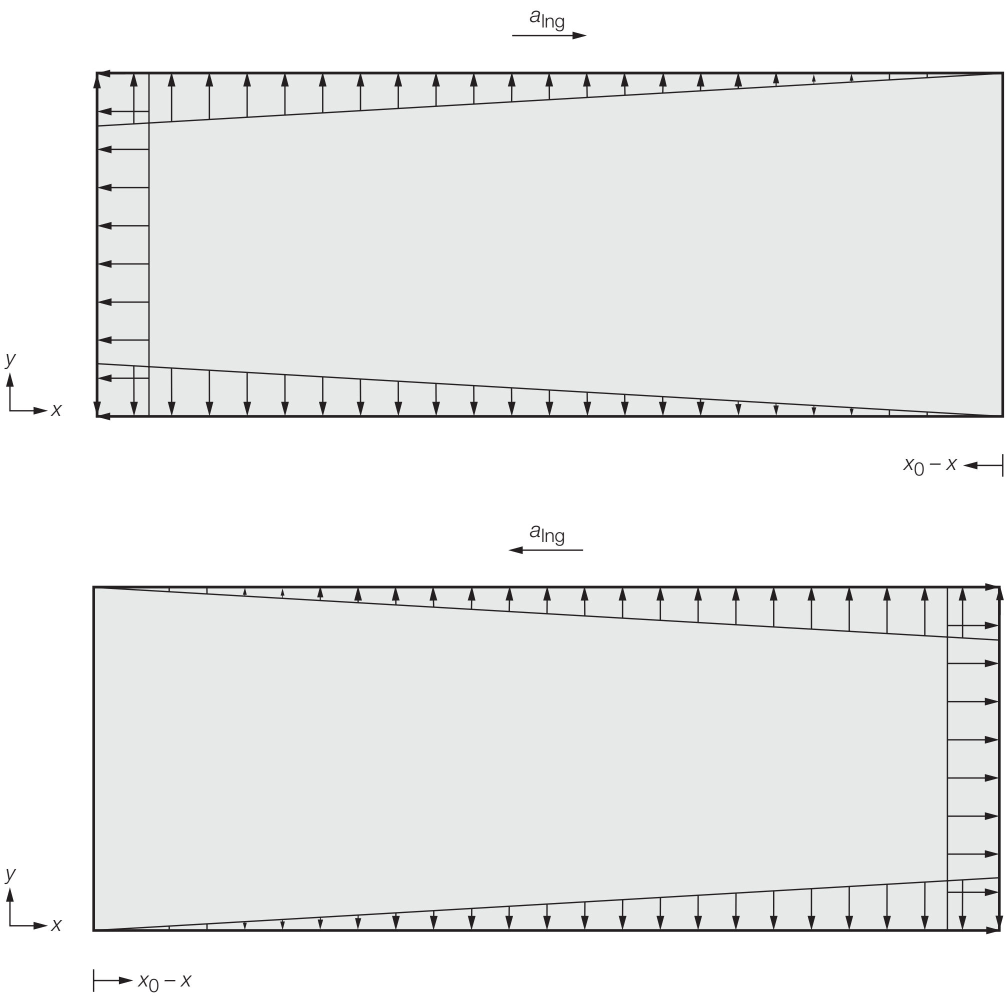


Fig. 2.6.6 Dynamic tank pressure in tanks due to positive and negative longitudinal acceleration

Section 7
Environmental loads for unrestricted worldwide transit condition

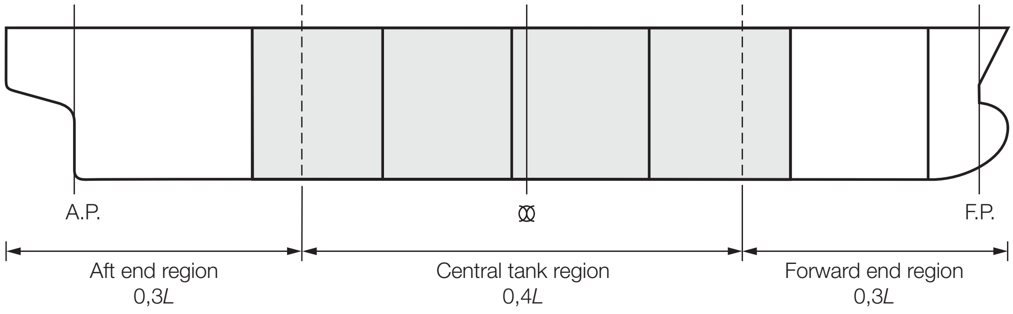
7.1 Dynamic load cases and dynamic load combination factors for strength assessment

7.1.1 **General**.

7.1.1.1 For the scantling requirements, the dynamic load cases are to be applied in accordance with the design load sets for the design load combination *S* + *D*. The simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in Appendix A for unrestricted world wide transit.

7.1.1.2 The Dynamic Load Combination Factors (DLCF) are dependent on the longitudinal position being considered. Tables are given in Appendix A for the longitudinal positions specified in Fig. 2.7.1, for light load and deep load draughts.

7.1.1.3 For the strength assessment by FEM, the simultaneously acting dynamic load cases are to be derived using the dynamic load combination factors given in Appendix A for unrestricted world wide transit.



NOTES
1. Dynamic load cases for the aft region are applicable to tanks and spaces with their longitudinal centre of gravity position aft of 0,3*L* from A.P.
2. Dynamic load cases for the central tank region are applicable to tanks and spaces with their longitudinal centre of gravity position at or forward of 0,3*L* from AP and at or aft of 0,7*L* from A.P.
3. Dynamic load cases for the forward region are applicable to tanks and spaces with their longitudinal centre of gravity position forward of 0,7*L* from A.P.
4. Where the Rule length, *L* is greater than 350 metres, special consideration will be required for the assignment of the structural regions to DLCF tables.

Fig. 2.7.1 Illustration of structural regions for DLCF Tables

■ *Section 8* Environmental loads for site-specific load scenarios

8.1 Site-specific dynamic load combination factors

8.1.1 **Application**.

8.1.1.1 Site-specific dynamic load combination factors (DLCFs) are to be derived from the environmental loads for the proposed area of operation. The simultaneously acting dynamic load cases are to be applied using the site-specific DLCFs.

8.1.1.2 The operating area notation will be assigned consistent with the geographic area used for the site-specific assessment.

8.1.1.3 The assessment of environmental loads is to consider Ch 1,5.1.3 for new-build units and Ch 1,6.1.3 for tanker conversions. *See also* Pt 4, Ch 3,4.1.

8.1.1.4 Alternative methods of establishing the environmental loads will be specially considered, provided that they are based on hindcast data, long-term measurements, global and local environmental theoretical models, or similar techniques. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

8.1.1.5 In order that an assessment of the design requirements can be made, the following information is to be submitted:
(a) Service area notation required together with the required extent of the operational area.
(b) The wave environmental parameters for the design.
(c) Specification of the environmental conditions used for the design assessment.

8.1.1.6 Dynamic Load Combination Factor (DLCF) Tables are specified in Appendix A for the geographic locations shown in Table 2.3.2 in Chapter 2. These Tables may be used for the initial design of units operating at these locations. The Tables may be used for on-site operation and inspection/maintenance load scenarios. The deep draught DLCF Table for the operational condition may be used for the initial design of units for the flooded case.
The DLCF Tables are dependent on the longitudinal position being considered. The Tables given in Appendix A have been derived for the longitudinal positions specified in Fig. 2.7.1, for light load and deep load draughts.

Section 1 Scantling requirements

1.1 Symbols

1.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres, as defined in Pt 4, Ch 1,5
B = moulded breadth, in metres, as defined in Pt 4, Ch 1,5
D = moulded depth, as defined in Pt 4, Ch 1,5
C_{wv} = wave coefficient, as defined in Ch 2,3.1
C_b = block coefficient, as defined in Pt 4, Ch 1,5, but is not to be taken as less than 0,7
ρ = density, tonnes/m^3, not to be taken less than specified values defined in Table 2.1.1 in Chapter 2
g = acceleration due to gravity, 9,81 m/s^2
k = higher strength steel factor, as defined in Ch 1,3.1.7.

1.2 Loading guidance

1.2.1.1 All units are to be provided with loading guidance information containing sufficient information to enable the loading, unloading and ballasting operations and inspection/maintenance of the unit within the stipulated operational limitations. The loading guidance information is to include an approved Loading Manual and Loading Computer System complying with the requirements given in Pt 3, Ch 4,8 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2.1.2 All relevant loading conditions and limitations are to be clearly stated in the loading manual. The loading computer system should be installed to monitor still water bending moments and shear forces and ensure they are maintained within the approved permissible levels.

1.3 Hull girder bending strength

1.3.1 General.

1.3.1.1 The hull girder section modulus requirements in 1.3.3 apply along the full length of the hull girder, from AP to FP.

1.3.1.2 Structural members included in the hull girder section modulus are to satisfy the buckling criteria given in 1.5.

1.3.2 Minimum requirements.

1.3.2.1 In order to limit the maximum permissible deflection, at the midship the net vertical hull girder section moment of inertia, $I_{v\text{-net50}}$,a about the horizontal neutral axis is not to be less than the following:

$$I_{v\text{-min}} = 2{,}7 C_{wv} L^3 B (C_b + 0{,}7)\, 10^{-8} \quad \text{m}^4.$$

where

$I_{v\text{-net50}}$ = net vertical hull girder section moment of inertia, in m^4, to be calculated in accordance with Ch 1,13.4.2.

1.3.2.2 Additional longitudinal strength and stiffness may be required to take account of the interaction between the hull structure and a liquefied gas cargo containment system if fitted.

1.3.3 Hull girder requirement on total design bending moment.

1.3.3.1 The net vertical hull girder section modulus requirement as defined in 1.3.3.2 is to be assessed for both hogging and sagging conditions.

1.3.3.2 The hull girder net section modulus, $Z_{v\text{-net50}}$, about the horizontal neutral axis is not to be less than the Rule required section modulus, based on the permissible still water and design wave bending moments as follows:

$$Z_{v\text{-req}} = \frac{|M_{sw\text{–}perm} + M_{wv\text{–}v}|}{\sigma_{perm}}\, 10^{-3} \quad \text{m}^3$$

where

$M_{sw\text{–}perm}$ = permissible hull girder hogging or sagging still water bending moment, in kNm, as given in Table 3.1.1
$M_{wv\text{–}v}$ = hogging or sagging vertical wave bending moment, in kNm, as given in Table 3.1.1
σ_{perm} = permissible hull girder bending stress as given in Table 3.1.1, in N/mm^2
$Z_{v\text{-net50}}$ = vertical hull girder net section modulus, in m^3, to be calculated in accordance with Ch 1,13.4.2.

1.4 Hull girder shear strength

1.4.1 General.

1.4.1.1 The hull girder shear strength requirements apply along the full length of the hull girder, from AP to FP.

Table 3.1.1 Loads and corresponding acceptance criteria for hull girder bending assessment

Design load combination	Still water bending moment, $M_{sw\text{-}perm}$	Vertical wave bending moment, $M_{wv\text{-}v}$	Permissible hull girder bending stress, σ_{perm}, *see* Note 1	
(S)	$M_{sw\text{-}perm}$	0	143/k	within 0,4L amidships
			105/k	at and forward of 0,9L from AP and at and aft of 0,1L from AP
(S + D)	$M_{sw\text{-}perm}$	$M_{wv\text{-}v}$	190/k	within 0,4L amidships
			140/k	at and forward of 0,9L from AP and at and aft of 0,1L from AP

Symbols

$M_{sw\text{-}perm}$ = permissible hull girder hogging and sagging still water bending moment for Static (S) or Static + Dynamic (S+D) design load combination, as applicable from Table 2.6.1 in Chapter 2, for the load case under consideration, in kNm

$M_{wv\text{-}v}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in Ch 2,3.7.1.1
$M_{wv\text{-}v}$ is to be taken as:
$M_{wv\text{-}hog}$ for assessment with respect to hogging vertical wave bending moment
$M_{wv\text{-}sag}$ for assessment with respect to sagging vertical wave bending moment

NOTES
1. σ_{perm} is to be linearly interpolated between values given.
2. For the flooded condition the permissible hull girder bending stress is to be taken as equal to the yield stress.

1.4.1.2 The following requirements are applicable to units with standard structural arrangements as shown in Fig. 3.1.1. Alternative configurations will be specially considered.

1.4.2 Assessment of hull girder shear strength.

1.4.2.1 The net hull girder shear strength capacity, $Q_{v\text{–}net50}$, is not to be less than the required vertical shear force, $Q_{v\text{–}req}$:

$$Q_{v\text{–}req} = Q_{sw\text{–}perm} + Q_{wv} \quad \text{kN}$$

where

$Q_{sw\text{–}perm}$ = permissible hull girder positive or negative still water shear force as given in Table 3.1.2, in kN

Q_{wv} = vertical wave positive or negative shear force as defined in Table 3.1.2, in kN.

1.4.2.2 The permissible positive and negative still water shear forces, $Q_{sw\text{-}perm}$, are to satisfy the following for each loading condition:

$$Q_{sw\text{–}perm} \le Q_{v\text{–}net50} - Q_{wv\text{–}pos} \quad \text{kN}$$

for maximum permissible positive shear force

$$Q_{sw\text{-}perm} \ge -Q_{v\text{–}net50} - Q_{wv\text{–}neg} \quad \text{kN}$$

for minimum permissible negative shear force

where

$Q_{v\text{-}net50}$ = net hull girder vertical shear strength to be taken as the minimum for all plate elements that contribute to the hull girder shear capacity

$$= \frac{\tau_{ij\,–\,perm}\, t_{ij\,–\,net50}}{1000 q_v} \quad \text{kN}$$

$\tau_{ij\text{–}perm}$ = permissible hull girder shear stress, τ_{perm}, as given in Table 3.1.2, in N/mm^2, for plate ij

$Q_{wv\text{-}pos}$ = positive vertical wave shear force, in kN, as defined in Table 3.1.2

$Q_{wv\text{-}neg}$ = negative vertical wave shear force, in kN, as defined in Table 3.1.2

$t_{ij\text{–}net50}$ = equivalent net thickness, t_{net50}, for plate ij, in mm. For longitudinal bulkheads between cargo tanks, t_{net50} is to be taken as $t_{sfc\text{-}net50}$ and $t_{str\text{-}k}$ as appropriate, *see* 1.4.3.1 and 1.4.4.1

t_{net50} = net thickness of plate, in mm
= $t_{grs} - 0{,}5 t_c$

t_{grs} = gross plate thickness, in mm. For corrugated bulkheads, to be taken as the minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$, in mm

$t_{w\text{-}grs}$ = gross thickness of the corrugation web, in mm

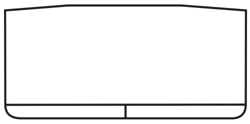
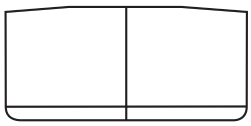
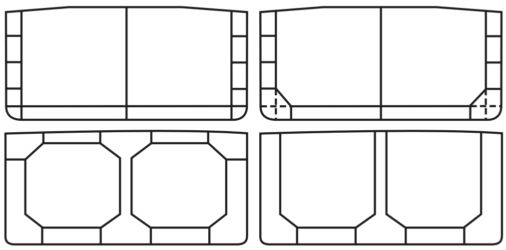
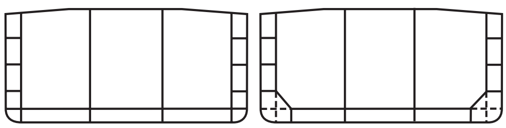
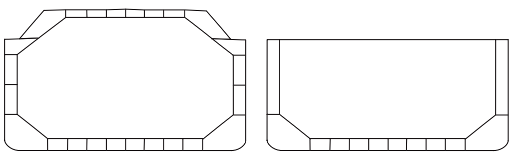
$t_{f\text{-}grs}$ = gross thickness of the corrugation flange, in mm

t_c = corrosion addition, in mm, as defined in Ch 1,12

q_v = unit shear flow per mm for the plate being considered and based on the net scantlings
Where direct calculation of the unit shear flow is not available, the unit shear flow may be taken equal to

$$= f_i \left(\frac{q_{1\text{-}net50}}{I_{v\text{-}net50}} \right) 10^{-9} \quad \text{mm}^{-1}$$

f_i = shear force distribution factor for the main longitudinal hull girder shear carrying members being considered. For standard structural configurations f_i is as defined in Fig. 3.1.1

Hull configuration	f_i factors
Outside cargo region (no longitudinal bulkhead) 	Side shell $f_1 = 0{,}5$
Outside cargo region (centreline bulkhead) 	Side shell $f_1 = 0{,}231 + 0{,}076 \dfrac{A_{1\text{-net50}}}{A_{3\text{-net50}}}$ Longitudinal bulkhead $f_3 = 0{,}538 - 0{,}152 \dfrac{A_{1\text{-net50}}}{A_{3\text{-net50}}}$
One centreline bulkhead 	Side shell $f_1 = 0{,}055 + 0{,}097 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0{,}020 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Inner hull $f_2 = 0{,}193 - 0{,}059 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0{,}058 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Longitudinal bulkhead $f_3 = 0{,}504 - 0{,}076 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} - 0{,}156 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$
Two longitudinal bulkheads 	Side shell $f_1 = 0{,}028 + 0{,}087 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0{,}023 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Inner hull $f_2 = 0{,}119 - 0{,}038 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} + 0{,}072 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$ Longitudinal bulkhead $f_3 = 0{,}353 - 0{,}049 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}} - 0{,}095 \dfrac{A_{2\text{-net50}}}{A_{3\text{-net50}}}$
Double hull, single cargo tank abreast 	Side shell $f_1 = 0{,}128 + 0{,}105 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}}$ Inner hull $f_2 = 0{,}372 - 0{,}105 \dfrac{A_{1\text{-net50}}}{A_{2\text{-net50}}}$

Symbols

i = index for the structural member under consideration
1, for the side shell
2, for the inner hull
3, for the longitudinal bulkhead

$A_{i\text{-net50}}$ = net area based on deduction $0{,}5t_c$, of the structural member, i, at one side of the section under consideration. The area $A_{3\text{-net50}}$ for the centreline bulkhead is not to be reduced for symmetry around the centreline

NOTES
1. The effective net hull girder vertical shear area includes the net plating area of the side shell including the bilge, the inner hull including the hopper side and the outboard girder under, the upper deck girder where applicable, and the longitudinal bulkheads including the double bottom girders in line.
2. For longitudinal strength members forming the web of the hull girder which are inclined to the vertical, the area of the member to be included in the shear force calculation is to be based on the projected area onto the vertical plane.

Fig. 3.1.1 Shear force distribution factors

Table 3.1.2 Loads and corresponding acceptance criteria for hull girder shear assessment

Design load combination	Still water shear force, $Q_{sw\text{-}perm}$	Vertical wave shear force, Q_{wv}	Permissible shear stress, τ_{perm}, *see* Note
(S)	$Q_{sw\text{-}perm}$	0	105/*k* for plate ij
(S + D)	$Q_{sw\text{-}perm}$	Q_{wv}	120/*k* for plate ij

Symbols

$Q_{sw\text{-}perm}$ = permissible positive or negative hull girder still water shear force for Static (S) or Static + Dynamic (S + D) design load combination, as applicable from Table 2.6.1 in Chapter 2 for the load case under consideration, in kN

Q_{wv} = positive or negative vertical wave shear, in kN, as defined in Ch 2,3.7.2.1. Q_{vw} is to be taken as:
$Q_{wv\text{-}pos}$ for assessment with respect to maximum positive permissible still water shear force
$Q_{wv\text{-}neg}$ for assessment with respect to minimum negative permissible still water shear force

plate ij = for each plate j, index i denotes the structural member of which the plate forms a component

NOTE
For the flooded condition the permissible hull girder shear stress is to be taken as equal to 0,58 yield stress.

$q_{1\text{-}net50}$ = first moment of area, in cm^3, about the horizontal neutral axis of the effective longitudinal members between the vertical level at which the shear stress is being determined and the vertical extremity, taken at the section being considered. The first moment of area is to be based on the net thickness, t_{net50}

$I_{v\text{-}net50}$ = net vertical hull girder section moment of inertia, in m^4 to be calculated in accordance with Chapter 1,13.4.2.

1.4.3 **Shear force correction for longitudinal bulkheads between cargo tanks.**

1.4.3.1 For longitudinal bulkheads between cargo tanks, the effective net plating thickness of the plating above the inner bottom, $t_{sfc\text{-}net50}$ for plate ij, used for calculation of hull girder shear strength, $Q_{v\text{-}net50}$, may be corrected for local shear distribution and is given by:

$$t_{sfc\text{-}net50} = t_{grs} - 0{,}5t_c - t_\Delta \text{ mm}$$

where

t_{grs} = gross plate thickness, in mm
t_c = corrosion addition, in mm, as defined in Ch 1,12
t_Δ = thickness deduction for plate ij, in mm, as defined in 1.4.3.2.

1.4.3.2 The vertical distribution of thickness reduction for shear force correction is assumed to be triangular, as indicated in Fig. 3.1.2. The thickness deduction, t_Δ, to account for shear force correction is to be taken as:

$$t_\Delta = \frac{\delta_{Q3}}{h_{blk}\,\tau_{ij\text{-}perm}}\left(1 - \frac{x_{blk}}{0{,}5l_{tk}}\right)\left(2 - \frac{2\,(z_p - h_{db})}{h_{blk}}\right) \text{ mm}$$

where

δ_{Q3} = shear force correction for longitudinal bulkhead as defined in 1.4.3.3 and 1.4.3.5 for ship units with one or two longitudinal bulkheads respectively, in kN
l_{tk} = length of cargo tank, in metres
h_{blk} = height of longitudinal bulkhead, in metres, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Fig. 3.1.2
x_{blk} = the minimum longitudinal distance from section considered to the nearest cargo tank transverse bulkhead, in metres. To be taken positive and not greater than $0{,}5l_{tk}$
z_p = the vertical distance from the lower edge of plate ij to the base line, in metres. Not to be taken as less than h_{db}
h_{db} = height of double bottom, in metres, as shown in Fig. 3.1.2
$\tau_{ij\text{-}perm}$ = permissible hull girder shear stress, τ_{perm}, in N/mm^2 for plate ij
= $120/k_{ij}$
k_{ij} = higher strength steel factor, *k*, for plate ij as defined in 1.1.

1.4.3.3 For ship units with a centreline bulkhead between the cargo tanks, the shear force correction in way of transverse bulkhead, δ_{Q3}, is to be taken as:

$$\delta_{Q3} = 0{,}5K_3\,F_{db} \text{ kN}$$

where

K_3 = correction factor, as defined in 1.4.3.4
F_{db} = maximum resulting force on the double bottom in a tank, in kN, as defined in 1.4.3.7.

1.4.3.4 For ship units with a centreline bulkhead between the cargo tanks, the correction factor, K_3, in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0{,}40\left(1 - \frac{1}{1+n}\right) - f_3\right]$$

where

n = number of floors between transverse bulkheads
f_3 = shear force distribution factor, *see* Fig. 3.1.1.

1.4.3.5 For ship units with two longitudinal bulkheads between the cargo tanks, the shear force correction, δ_{Q3}, is to be taken as:

$$\delta_{Q3} = 0{,}5K_3\,F_{db} \text{ kN}$$

where

K_3 = correction factor, as defined in 1.4.3.6
F_{db} = maximum resulting force on the double bottom in a tank, in kN, as defined in 1.4.3.7.

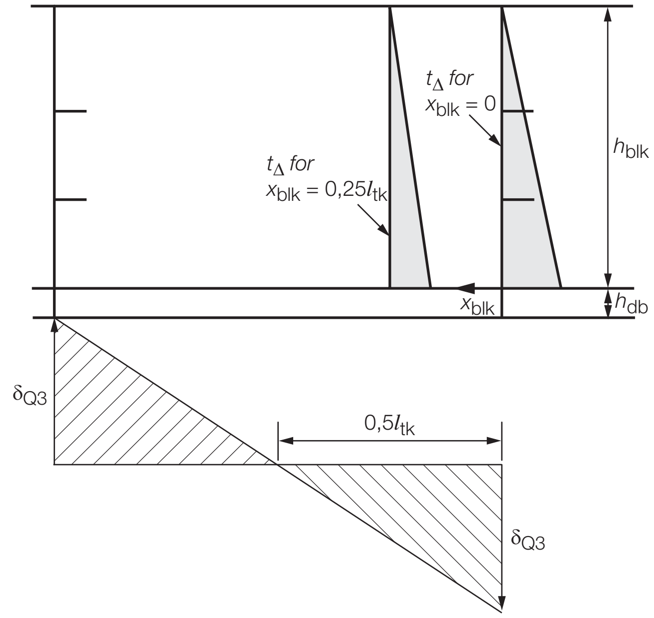


Fig. 3.1.2 Shear force correction for longitudinal bulkheads

1.4.3.6 For ship units with two longitudinal bulkheads between the cargo tanks, the correction factor, K_3, in way of transverse bulkheads is to be taken as:

$$K_3 = \left[0,5\left(1 - \frac{1}{1+n}\right)\left(\frac{1}{r+1}\right) - f_3\right]$$

where

n = number of floors between transverse bulkheads

r = ratio of the part load carried by the wash bulkheads and floors from longitudinal bulkhead to the double side and is given by

$$r = \frac{1}{\left[\dfrac{A_{3\text{-net50}}}{A_{1\text{-net50}} + A_{2\text{-net50}}} + \dfrac{2 \times 10^4\, b_{80}\,(n_s + 1)\, A_{3\text{-net50}}}{l_{tk}\,(n_s\, A_{T\text{-net50}} + R)}\right]}$$

NOTE

For preliminary calculations, r may be taken as 0,5

l_{tk} = length of cargo tank, between transverse bulkheads in the side cargo tank, in metres

b_{80} = 80 per cent of the distance from longitudinal bulkhead to the inner hull longitudinal bulkhead, in metres, at tank mid length

$A_{T\text{-net50}}$ = net shear area of the transverse wash bulkhead, including the double bottom floor directly below, in the side cargo tank, in cm^2, taken as the smallest area in a vertical section. $A_{T\text{-net50}}$ is to be calculated with net thickness given by $t_{grs} - 0{,}5t_c$

$A_{1\text{-net50}}$ = net area, as shown in Fig. 3.1.1, in m^2

$A_{2\text{-net50}}$ = net area, as shown in Fig. 3.1.1, in m^2

$A_{3\text{-net50}}$ = net area, as shown in Fig. 3.1.1, in m^2

f_3 = shear force distribution factor, as shown in Fig. 3.1.1

n_s = number of wash bulkheads in the side cargo tank

R = total efficiency of the transverse primary support members in the side tank

$$R = \left(\frac{n - n_s}{2} - 1\right)\frac{A_{Q\text{-net50}}}{\gamma} \quad \text{cm}^2$$

$$\gamma = 1 + \frac{300\, b_{80}^2\, A_{Q\text{-net50}}}{I_{psm\text{-net50}}}$$

$A_{Q\text{-net50}}$ = net shear area, in cm^2, of a transverse primary support member in the wing cargo tank, taken as the sum of the net shear areas of floor, cross ties and deck transverse webs
$A_{Q\text{-net50}}$ is to be calculated using the net thickness given by $t_{grs} - 0{,}5t_c$ .The net shear area is to be calculated at the midspan of the members

$I_{psm\text{-net50}}$ = net moment of inertia for primary support members, in cm^4, of a transverse primary support member in the wing cargo tank, taken as the sum of the moments of inertia of transverses and cross ties. It is to be calculated using the net thickness given by $t_{grs} - 0{,}5t_c$. The net moment of inertia is to be calculated at the midspan of the member, including an attached plate width equal to the primary support member spacing

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in Ch 1,12.

1.4.3.7 The maximum resulting force on the double bottom in a tank, F_{db}, is to be taken as:

$$F_{db} = g\,|W_{CT} + W_{CWBT} - \rho_{sw}\, b_2\, l_{tk}\, T_{mean}| \quad \text{kN}$$

where

W_{CT} = weight of cargo, in tonnes, as defined in Table 3.1.3

W_{CWBT} = weight of ballast, in tonnes, as defined in Table 3.1.3

b_2 = breadth, in metres, as defined in Table 3.1.3

l_{tk} = length of cargo tank, between watertight transverse bulkheads in the wing cargo tank, in metres

T_{mean} = draught at the mid length of the tank for the loading condition considered, in metres.

1.4.3.8 The maximum resulting force on the double bottom in a tank, F_{db}, is in no case to be less than that given by the Rule minimum conditions given in Table 3.1.4. Where other tank configurations are proposed, the equivalent loading scenario is to be considered.

1.4.4 **Shear force correction due to loads from transverse bulkhead stringers**.

1.4.4.1 In way of transverse bulkhead stringer connections, within areas as specified in Fig. 3.1.6, the equivalent net thickness of plate used for calculation of the hull girder shear strength, $t_{str\text{-}k}$, where the index *k* refers to the identification number of the stringer, is not to be taken greater than:

$$t_{str\text{–}k} = t_{sfc\text{-}net50}\left(1 - \frac{\tau_{str}}{\tau_{ij\text{-}perm}}\right) \quad \text{mm}$$

where

$t_{sfc\text{-}net50}$ = effective net plating thickness, in mm, as defined in 1.4.3.1 and calculated at the transverse bulkhead for the height corresponding to the level of the stringer

$\tau_{ij\text{-}perm}$ = permissible hull girder shear stress, τ_{perm}, for plate ij
= $120/k_{ij}$ N/mm^2

k_{ij} = higher strength steel factor, *k*, for plate ij, as defined in 1.1

$$\tau_{str} = \frac{Q_{str\text{-}k}}{l_{str}\, t_{sfc\text{-}net50}} \quad \text{N/mm}^2$$

l_{str} = connection length of stringer, in metres, *see* Fig. 3.1.4

$Q_{str\text{-}k}$ = shear force on the longitudinal bulkhead from the stringer in loaded condition with tanks abreast full
$= 0{,}8F_{str\text{–}k}\left(1 - \dfrac{z_{str} - h_{db}}{h_{bhd}}\right)$ kN

$F_{str\text{-}k}$ = total stringer supporting force, in kN, as defined in 1.4.4.2

h_{db} = the double bottom height, in metres, as shown in Fig. 3.1.5

h_{blk} = height of bulkhead, in metres, defined as the distance from inner bottom to the deck at the top of the bulkhead, as shown in Fig. 3.1.5

z_{str} = the vertical distance from baseline to the considered stringer, in metres.

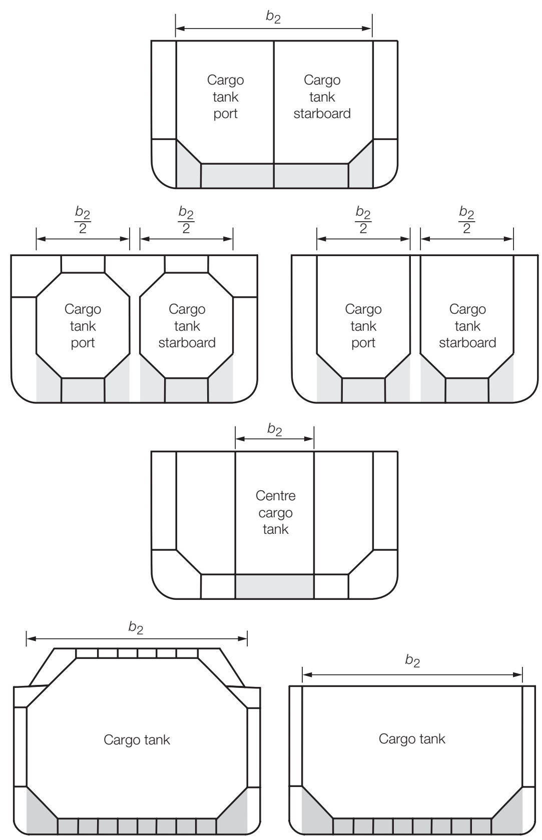


Fig. 3.1.3
Tank breadth to be included for standard tank configuration

1.4.4.2 The total stringer supporting force, $F_{str\text{-}k}$, in way of a longitudinal bulkhead is to be taken as:

$$F_{str\text{-}k} = \frac{P_{str}\, b_{str}\,(h_k + h_{k-1})}{2} \quad \text{kN}$$

where

P_{str} = pressure on stringer, in kN/m^2, to be taken as $10h_{tt}$

h_{tt} = the height from the top of the tank to the midpoint of the load area between $h_k/2$ below the stringer and $h_{k\text{-}1}/2$ above the stringer, in metres

h_k = the vertical distance from the considered stringer to the stringer below. For the lowermost stringer, it is to be taken as 80 per cent of the average vertical distance to the inner bottom, in metres

$h_{k\text{-}1}$ = the vertical distance from the considered stringer to the stringer above. For the uppermost stringer, it is to be taken as 80 per cent of the average vertical distance to the upper deck, in metres

b_{str} = load breadth acting on the stringer, in metres, *see* Fig. 3.1.6 and Fig. 3.1.7.

Table 3.1.3 Design conditions for double bottoms

Structural configuration	W_{CT}	W_{CWBT}	b_2
Ship units with one longitudinal bulkhead	Weight of cargo in cargo tanks, in tonnes, using a minimum specific gravity of 1,025 tonnes/m^3	Weight of ballast between port and starboard inner sides, in tonnes	Maximum breadth between port and starboard inner sides at mid length of tank, in metres, as shown in Fig. 3.1.3
Ship units with two cargo tanks abreast with a centreline cofferdam	Weight of cargo in cargo tanks, in tonnes, using the specific gravity of the cargo as shown in Table 2.1.1 in Chapter 2 for strength assessment	Weight of ballast below the cargo tanks, in tonnes	Total breadth of the portion of the ballast tanks below the cargo tanks, in metres as shown in Fig. 3.1.3
Ship units with two longitudinal bulkheads	Weight of cargo in the centre tank, in tonnes, using a minimum specific gravity of 1,025 tonnes/m^3	Weight of ballast below the centre cargo tank, in tonnes	Maximum breadth of the centre cargo tank at mid length of tank, in metres, as shown in Fig. 3.1.3
Ship units with a single cargo tank abreast	Weight of cargo in cargo tank, in tonnes, using the specific gravity of the cargo as shown in Table 2.1.1 in Chapter 2 for strength assessment	Weight of ballast below the cargo tank, in tonnes	Breadth of the ballast tanks below the cargo tank, in metres, as shown in Fig. 3.1.3

Table 3.1.4 Rule minimum conditions for double bottoms

Structural configuration	Positive/negative force, F_{db}	Minimum condition
Ship units with one longitudinal bulkhead	Max. positive net vertical force, F_{db} +	0,9T_{SC} and empty cargo and ballast tanks
	Max. negative net vertical force, F_{db} –	0,6T_{SC} and full cargo tanks and empty ballast tanks
Ship units with two longitudinal bulkheads	Min. positive net vertical force, F_{db} +	0,9T_{SC} and empty cargo and ballast tanks
	Min. negative net vertical force, F_{db} –	0,6T_{SC} and full centre cargo tank and empty ballast tanks

1.4.4.3 Where reinforcement is provided to meet the above requirement, the reinforced area based on $t_{str\text{-}k}$ is to extend longitudinally for the full length of the stringer connection and a minimum of one frame spacing forward and aft of the bulkhead. The reinforced area shall extend vertically from above the stringer level and down to 0,5h_k below the stringer, where h_k, the vertical distance from the considered stringer to the stringer below, is as defined in 1.4.4.2. For the lowermost stringer, the plate thickness requirement $t_{str\text{-}k}$ is to extend down to the inner bottom, *see* Fig. 3.1.6.

1.5 Hull girder buckling strength

1.5.1 **General**.

1.5.1.1 These requirements apply to plate panels and longitudinals subject to hull girder compression and shear stresses. These stresses are to be based on the permissible values for wave bending moments and shear forces given in Ch 2,2.2 and 3.7.

1.5.1.2 The hull girder buckling strength requirements apply along the full length of the ship unit, from AP to FP.

1.5.1.3 For the purposes of assessing the hull girder buckling strength in this sub-Section, the following are to be considered separately:

(a) Axial hull girder compressive stress to satisfy requirements in 1.5.2.6 and 1.5.2.8.
(b) Hull girder shear stress to satisfy requirements in 1.5.2.7.

1.5.2 **Buckling assessment.**

1.5.2.1 The buckling assessment of plate panels and longitudinals is to be determined according to Ch 1,18, with hull girder stresses calculated on net hull girder sectional properties.

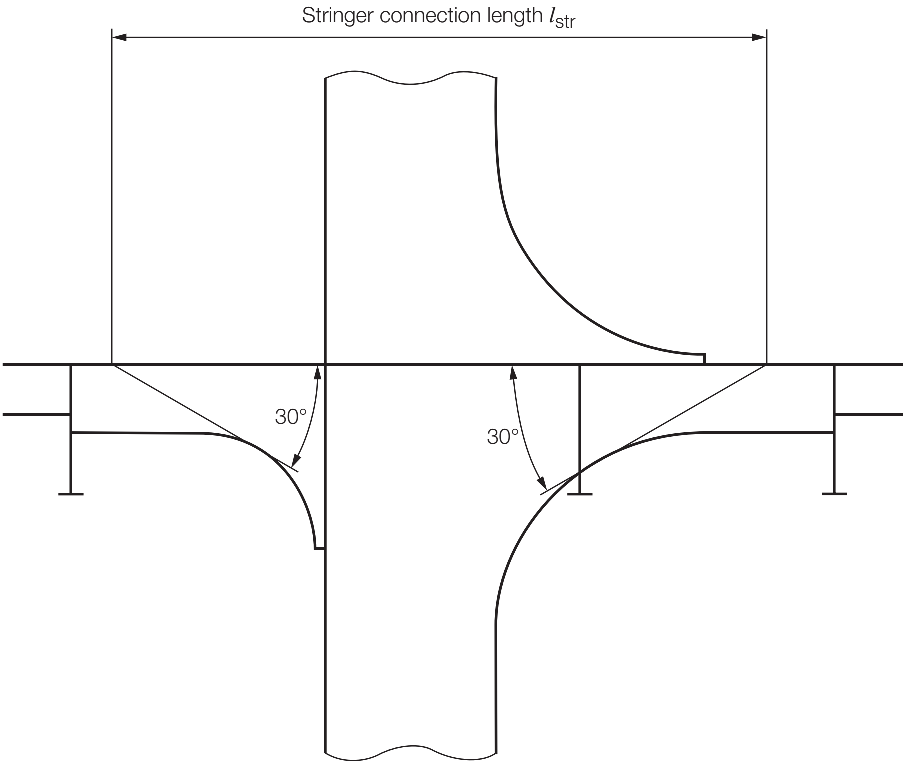


Fig. 3.1.4 Effective connection length of stringer

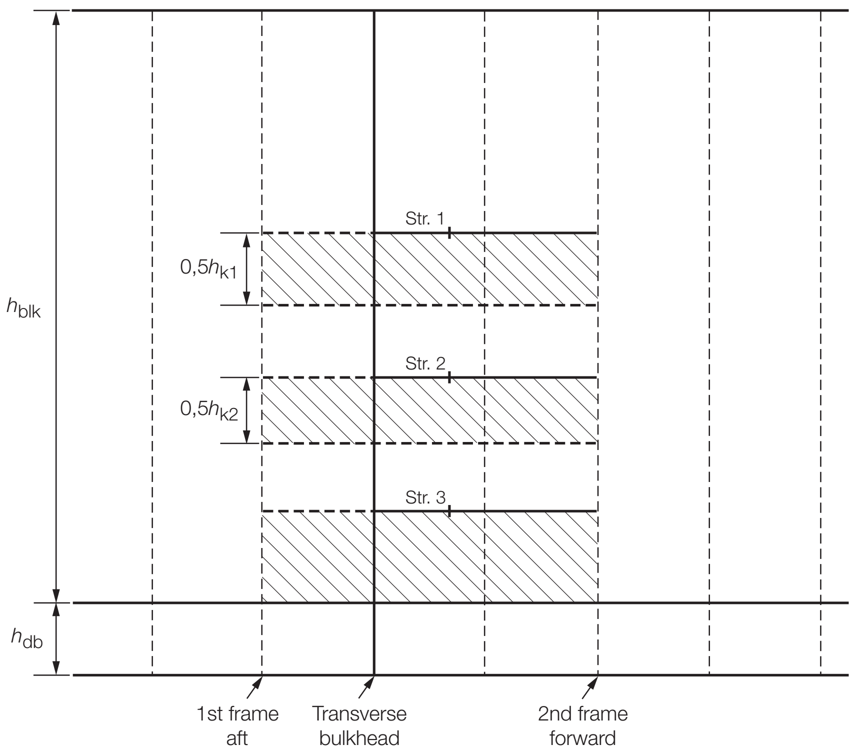


Fig. 3.1.5 Region for stringer correction, t_{ij}, for a unit with three stringers

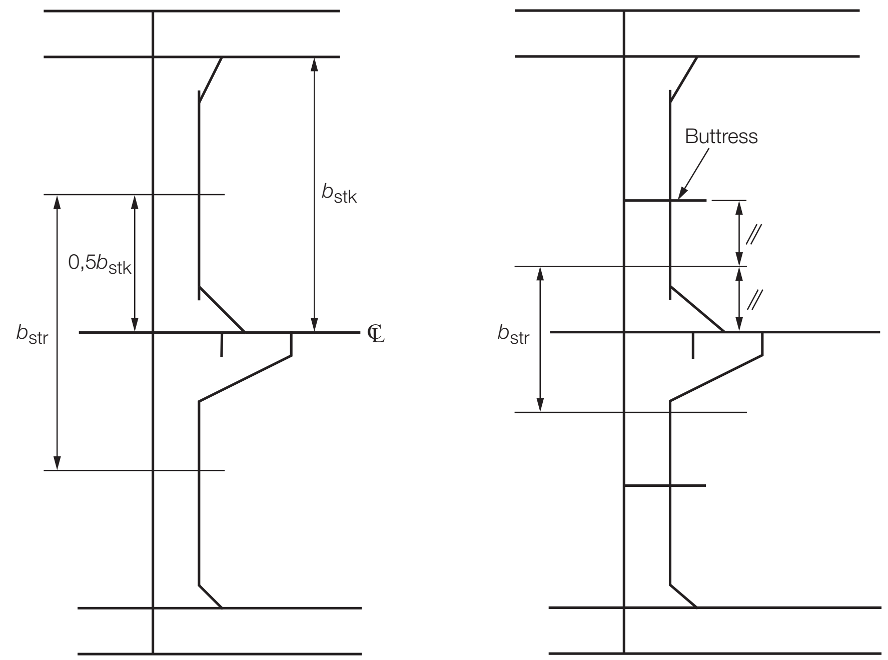


Fig. 3.1.6 Load breadth of stringers for units with a centreline bulkhead

1.5.2.2 The buckling strength for the buckling assessment is to be derived using local net scantlings, t_{net}, as follows:

$$t_{net} = t_{grs} - 1{,}0t_c \quad \text{mm}$$

where

t_{grs} = gross plate thickness, in mm
t_c = corrosion addition, in mm, as defined in Ch 1,12.

1.5.2.3 The hull girder compressive stress due to bending, $\sigma_{hg\text{-}net50}$, for the buckling assessment is to be calculated using net hull girder sectional properties and is to be taken as the greater of the following:

$$\sigma_{hg\text{-}net50} = \left| \frac{(z - z_{NA\text{-}net50})\,(M_{sw\text{-}perm} + M_{wv\text{-}v})}{I_{v\text{-}net50}} \right| 10^{-3} \text{ N/mm}^2$$

$$\sigma_{hg\text{-}net50} = \frac{30}{k} \text{ N/mm}^2$$

where

$M_{sw\text{-}perm}$ = permissible still water bending moment for the Static + Dynamic (S+D) design load combination, as applicable from Table 2.6.1 for the load case under consideration, in kNm, with signs as given in Ch 2,1.2.2.4
$M_{wv\text{-}v}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in Chapter 2, with signs as given in Ch 2,1.2.2.4
$M_{wv\text{-}v}$ is to be taken as:
$M_{wv\text{-}hog}$ for assessment with the hogging still water bending moment
$M_{wv\text{-}sag}$ for assessment with the sagging still water bending moment
z = distance from the structural member under consideration to the baseline, in metres
$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres
$I_{v\text{-}net50}$ = net vertical hull girder section moment of inertia, in m^4.

1.5.2.4 The sagging bending moment values of $M_{sw\text{-}perm}$ and $M_{wv\text{-}v}$, are to be taken for members above the neutral axis. The hogging bending moment values are to be taken for members below the neutral axis.

1.5.2.5 The design hull girder shear stress for the buckling assessment, $\tau_{hg\text{-}net50}$, is to be calculated based on net hull girder sectional properties and is to be taken as:

$$\tau_{hg\text{-}net50} = \left| (Q_{sw\text{-}perm} + Q_{wv}) \left(\frac{1000q_v}{t_{ij\text{-}net50}} \right) \right| \quad \text{N/mm}^2$$

where

$Q_{sw\text{-}perm}$ = positive and negative still water permissible shear force for Static + Dynamic (S+D) design load combination, as applicable from Table 2.6.1 in Chapter 2 for the load case under consideration, in kN
Q_{wv} = positive or negative vertical wave shear, in kN, as defined in Chapter 2
Q_{vw} is to be taken as:
$Q_{wv\text{-}pos}$ for assessment with the positive permissible still water shear force
$Q_{wv\text{-}neg}$ for assessment with the negative permissible still water shear force
$t_{ij\text{-}net50}$ = net thickness for the plate ij, in mm
= $t_{ij\text{-}grs} - 0{,}5t_c$
$t_{ij\text{-}grs}$ = gross plate thickness of plate ij, in mm. The gross plate thickness for corrugated bulkheads is to be taken as the minimum of $t_{w\text{-}grs}$ and $t_{f\text{-}grs}$, in mm
$t_{w\text{-}grs}$ = gross thickness of the corrugation web, in mm
$t_{f\text{-}grs}$ = gross thickness of the corrugation flange, in mm
t_c = corrosion addition, in mm, as defined in Ch 1,12
q_v = unit shear per mm for the plate being considered, defined in 1.4.2.2

NOTES
1. Maximum of the positive shear (still water + vertical wave) and negative shear (still water + vertical wave) is to be used as the basis for calculation of design shear stress.
2. All plate elements ij that contribute to the hull girder shear capacity are to be assessed. *See also* Table 3.1.2 and Fig. 3.1.1.

1.5.2.6 The compressive buckling strength of plate panels is to satisfy the following criteria:

$\eta \leq \eta_{allow}$

where

η = buckling utilisation factor

$$\frac{\sigma_{hg-net50}}{\sigma_{cr}}$$

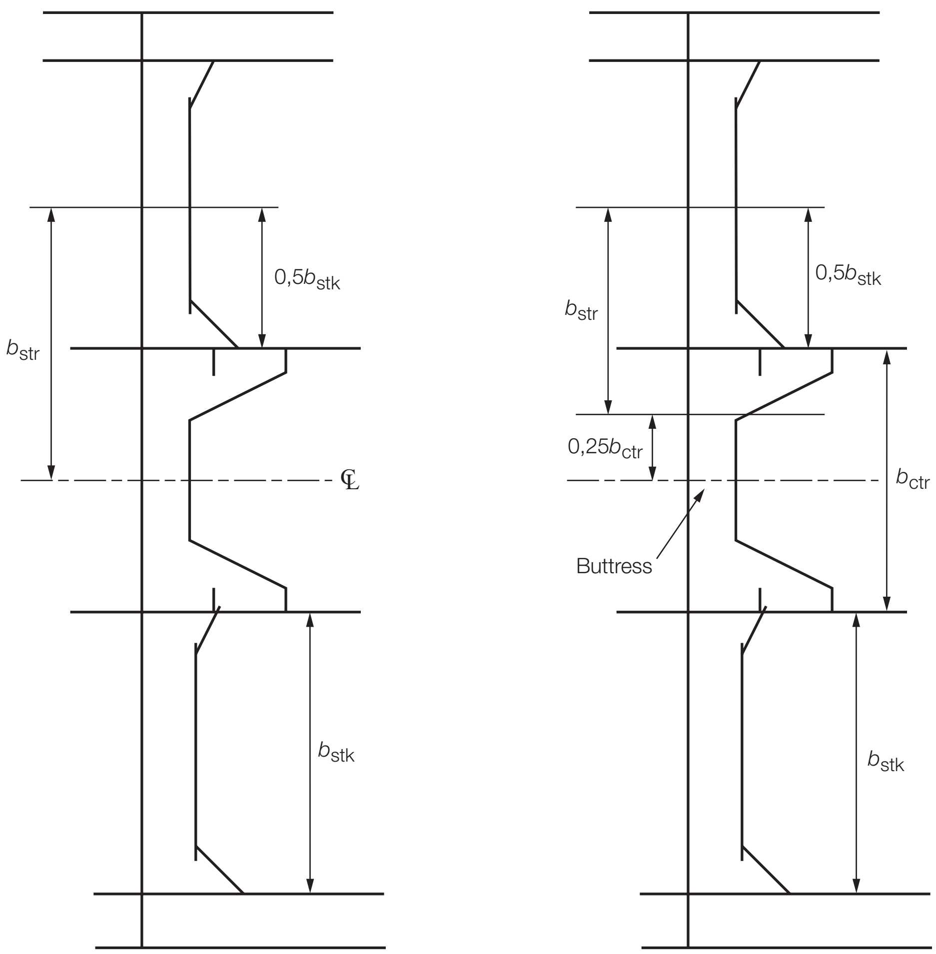
$\sigma_{hg\text{-}net50}$ = hull girder compressive stress based on net hull girder sectional properties, in N/mm^2, as defined in 1.5.2.3

σ_{cr} = critical compressive buckling stress, σ_{xcr} or σ_{ycr} as appropriate, in N/mm^2, as specified in Ch 1,18.2.1.3. The critical compressive buckling stress is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness given as $t_{grs} - t_c$ as described in Ch 1,12 is to be used for the calculation of σ_{cr}

η_{allow} = allowable buckling utilisation factor
= 1,0 for plate panels at or above 0,5*D*
= 0,90 for plate panels below 0,5*D*

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in Ch 1,12.



NOTES
1. b_{stk} is the breadth of wing cargo tank, in metres.
2. b_{ctr} is the breadth of centre cargo tank, in metres.

Fig. 3.1.7 Load breadth of stringers for units with two inner longitudinal bulkheads

1.5.2.7 The shear buckling strength of plate panels, is to satisfy the following criteria:

$$\eta \leq \eta_{allow}$$

where

η = buckling utilisation factor

$$\frac{\tau_{hg-net50}}{\tau_{cr}}$$

$\tau_{hg\text{-}net50}$ = design hull girder shear stress, in N/mm^2, as defined in 1.5.2.5

τ_{cr} = critical shear buckling stress, in N/mm^2, specified in Ch 1,18.2.1.3. The critical shear buckling stress is to be calculated for the effects of hull girder shear stress only. The effects of other membrane stresses and lateral pressure are to be ignored. The net thickness $t_{grs} - t_c$ as described in Ch 1,12 is to be used for the calculation of τ_{cr}

η_{allow} = allowable buckling utilisation factor
= 0,95

t_{grs} = gross plate thickness, in mm

t_c = corrosion addition, in mm, as defined in Ch 1,12.

1.5.2.8 The compressive buckling strength of longitudinal stiffeners is to satisfy the following criteria:

$$\eta \leq \eta_{allow}$$

where

η = the greater of the buckling utilisation factors given in Ch 1,18.3.2.1 and 18.3.3.1. The buckling utilisation factor is to be calculated for the effects of hull girder compressive stress only. The effects of other membrane stresses and lateral pressure are to be ignored

η_{allow} = allowable buckling utilisation factor
= 1,0 for stiffeners at or above 0,5D
= 0,90 for stiffeners below 0,5D.

1.6 Tapering and structural continuity of longitudinal hull girder elements

1.6.1 **Tapering based on minimum hull girder section property requirements**.

1.6.1.1 Scantlings required by the Rule minimum moment of inertia and section modulus may be gradually reduced to the local requirements at the ends, provided the hull girder bending and buckling requirements, as given in 1.3.3 and 1.5, are complied with along the full length of the ship unit.

1.6.2 **Longitudinal extent of higher strength steel**.

1.6.2.1 Where used, the application of higher strength steel is to be continuous over the length of the ship unit up to locations where the longitudinal stress levels are within the allowable range for mild steel structure.

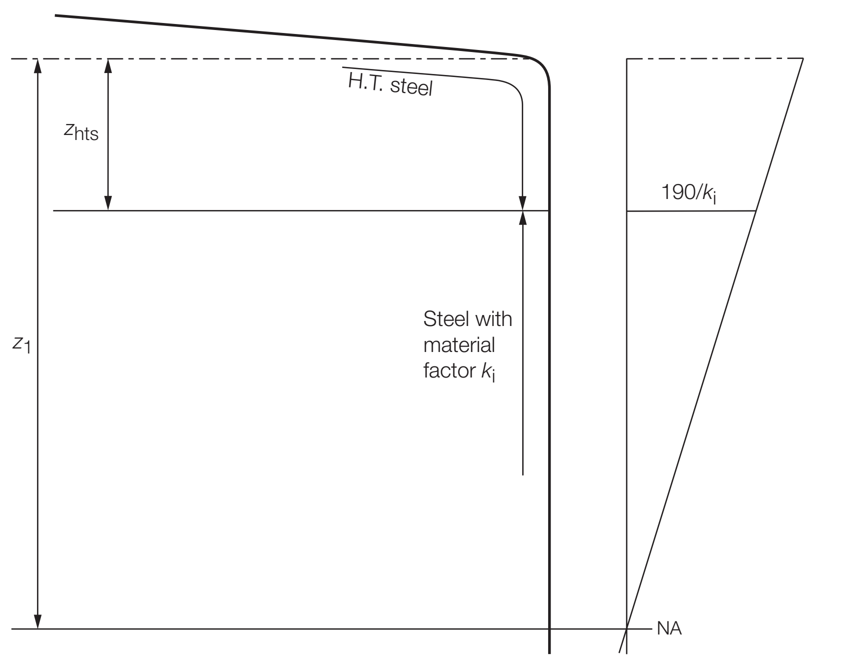


Fig. 3.1.8 Vertical extent of higher strength steel

1.6.3 **Vertical extent of higher strength steel**.

1.6.3.1 The vertical extent of higher strength steel, z_{hts}, used in the deck or bottom and measured from the moulded deck line at side or keel is not to be taken less than the following, *see also* Fig. 3.1.8.

$$z_{hts} = z_1 \left(1 - \frac{190}{\sigma_1 k_i}\right) \text{ m}$$

where

z_1 = distance from horizontal neutral axis to moulded deck line or keel respectively, in metres

σ_1 = to be taken as σ_{dk} or σ_{kl} for the hull girder deck and keel respectively, in N/mm^2

σ_{dk} = hull girder bending stress at moulded deck line given by

$$\frac{|M_{sw\text{-}perm} + M_{wv\text{-}v}|}{I_{v\text{-}net50}} (z_{dk\text{-}side} - z_{NA\text{-}net50})\, 10^{-3} \text{ N/mm}^2$$

σ_{kl} = hull girder bending stress at keel given by

$$\frac{|M_{sw\text{-}perm} + M_{wv\text{-}v}|}{I_{v\text{-}net50}} (z_{NA\text{-}net50} - z_{kl}) 10^{-3} \text{ N/mm}^2$$

$M_{sw\text{-}perm}$ = permissible hull girder still water bending moment for applicable static + dynamic condition, in kNm, as defined in Table 2.6.1 in Chapter 2

$M_{wv\text{-}v}$ = hogging and sagging vertical wave bending moments, in kNm, as defined in 1.2.2.4. $M_{wv\text{-}v}$ is to be taken as:
$M_{wv\text{-}hog}$ for assessment with respect to hogging vertical wave bending moment
$M_{wv\text{-}sag}$ for assessment with respect to sagging vertical wave bending moment

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, in m^4

$z_{dk\text{-}side}$ = distance from baseline to moulded deck line at side, in metres

z_{kl} = vertical distance from the baseline to the keel, in metres

$z_{NA\text{-}net50}$ = distance from baseline to horizontal neutral axis, in metres

k_i = higher strength steel factor for the area *i* defined in Fig. 3.1.8. The factor, *k*, is defined in 1.1.

1.6.4 **Tapering of plate thickness due to hull girder shear requirement**.

1.6.4.1 Longitudinal tapering of shear reinforcement is permitted, provided that the requirements given in 1.4.2 are complied with for any longitudinal position.

1.6.5 **Structural continuity of longitudinal bulkheads**.

1.6.5.1 Suitable scarphing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes. In particular, longitudinal bulkheads are to be terminated at an effective transverse bulkhead and large transition brackets shall be fitted in line with the longitudinal bulkhead.

1.6.6 **Structural continuity of longitudinal stiffeners.**

1.6.6.1 Where longitudinal stiffeners terminate, and are replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover.

1.6.6.2 Where a deck longitudinal stiffener is cut, in way of an opening, compensation is to be arranged to ensure structural continuity of the area. The compensation area is to extend well beyond the forward and aft ends of the opening and not be less than the area of the longitudinal that is cut. Stress concentration in way of the stiffener termination and the associated buckling strength of the plate and panel is to be considered.

1.7 Standard construction details

1.7.1 Details to be submitted:

1.7.1.1 A booklet of standard construction details is to be submitted for review. It is to include the following:

(a) the proportions of built-up members to demonstrate compliance with established standards for structural stability.
(b) the design of structural details which reduce the harmful effects of stress concentrations, notches and material fatigue, such as:
    - details of the ends, at the intersections of members and associated brackets;
    - shape and location of air, drainage, and/or lightening holes;
    - shape and reinforcement of slots or cut-outs for internals;
    - elimination or closing of weld scallops in way of butts, ‘softening’ of bracket toes, reduction of abrupt changes of section or structural discontinuities;
    - proportion and thickness of structural members to reduce fatigue response due to machinery operational and/or wave induced cyclic stresses, particularly for higher strength steels.

1.8 Termination of local support members

1.8.1 **General**.

1.8.1.1 In general, structural members are to be effectively connected to adjacent structures to avoid hard spots, notches and stress concentrations.

1.8.1.2 Where a structural member is terminated, structural continuity is to be maintained by suitable back-up structure fitted in way of the end connection of frames, or the end connection is to be effectively extended with additional structure and integrated with an adjacent beam, stiffener, etc.

1.8.1.3 All types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) are to be connected at their ends. However, in special cases, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in 1.8.3 to 1.8.5.

1.8.2 **Longitudinal members**.

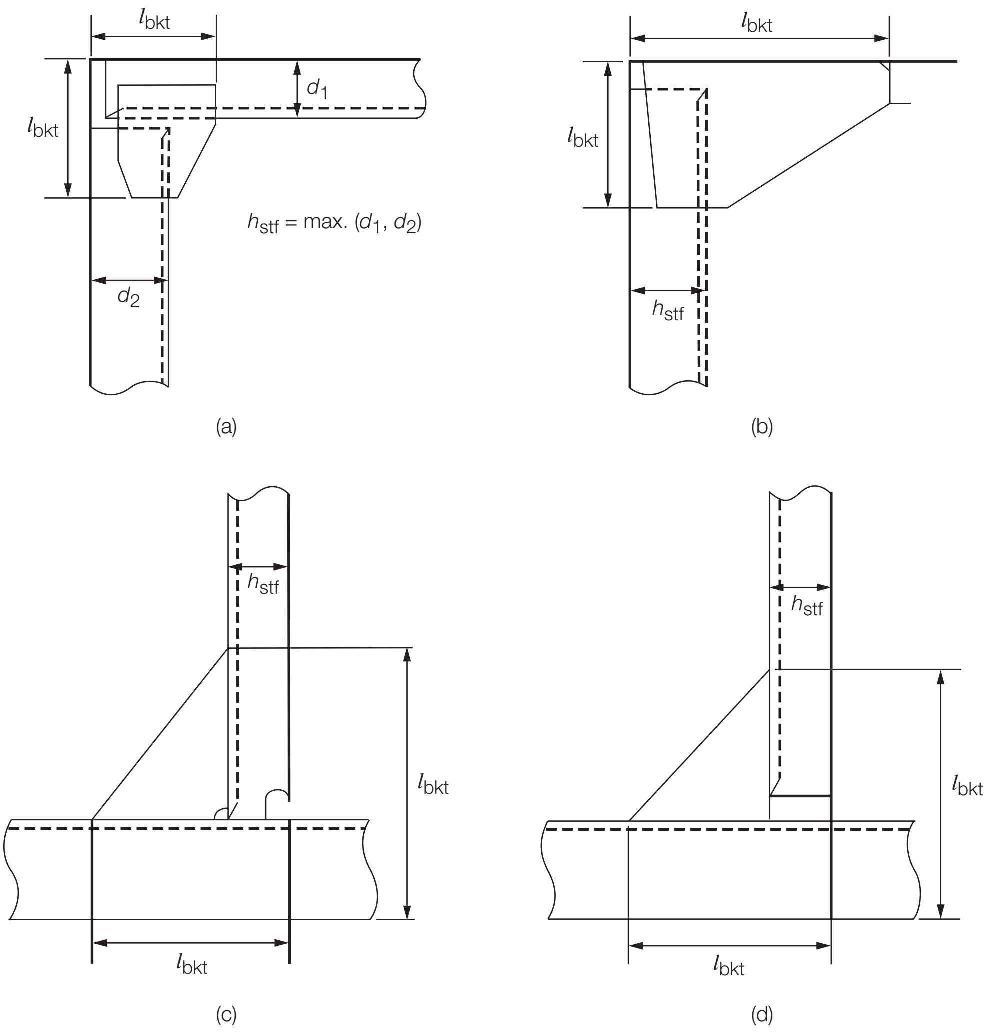
1.8.2.1 All longitudinals are to be kept continuous within the 0,4L amidships cargo tank region. In special cases, in way of large openings, foundations and partial girders, the longitudinals may be terminated, but end connection and welding are to be specially considered.

1.8.2.2 Where continuity of strength of longitudinal members is provided by brackets, the correct alignment of the brackets on each side of the primary support member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

1.8.3 **Bracketed connections**.

1.8.3.1 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member. The brackets are to have scantlings, sufficient to compensate for the non-continuous stiffener flange or non-continuous stiffener.

1.8.3.2 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section modulus less than that required for the stiffener.



NOTE
For stiffeners of configuration (b) that are not lapped, the bracket arm length l_{bkt} is not to be less than the stiffener height h_{stf}.
For stiffener arrangements similar to (c) and (d) where the smaller attached stiffener, labelled as h_{stf}, is connected to a primary support member or bulkhead, the height of the bracket is not to be less than the height of the attached stiffener, h_{stf}.

Fig. 3.1.9 Bracket arm length

1.8.3.3 Minimum net bracket thickness, $t_{bkt\text{-}net}$, is to be taken as:

$$t_{bkt\text{-}net} = (2 + f_{bkt}\, Z_{rl\text{-}net}) \left(\sqrt{\frac{\sigma_{yd\text{-}stf}}{\sigma_{yd\text{-}bkt}}} \right) \text{ mm}$$

but is not to be less than 6 mm and need not be greater than 13,5 mm

where:

f_{bkt} = 0,2 for brackets with flange or edge stiffener
= 0,3 for brackets without flange or edge stiffener

$Z_{rl\text{-}net}$ = net Rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$\sigma_{yd\text{-}stf}$ = specified minimum yield stress of the material of the stiffener, in N/mm^2

$\sigma_{yd\text{-}bkt}$ = specified minimum yield stress of the material of the bracket, in N/mm^2.

1.8.3.4 Brackets to provide fixity of end rotation are to be fitted at the ends of discontinuous local support members, except as otherwise permitted by 1.8.4. The end brackets are to have arm lengths, l_{bkt}, not less than:

$$l_{bkt} = c_{bkt} \sqrt{\frac{Z_{rl\text{-}net}}{t_{bkt\text{-}net}}} \text{ mm, but is not to be less than:}$$

(a) 1,8 times the depth of the stiffener web for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, *see* Fig. 3.1.9(c)
(b) 2,0 times for other cases, *see* Fig. 3.1.9(a), (b) and (d)

where

c_{bkt} = 65 for brackets with flange or edge stiffener
= 70 for brackets without flange or edge stiffener

$Z_{rl\text{-}net}$ = net Rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener

$t_{bkt\text{-}net}$ = minimum net bracket thickness, as defined in 1.8.3.3.

1.8.3.5 Where an edge stiffener is required, the depth of stiffener web, d_w, is not to be less than:

$$d_w = 45 \left(1 + \frac{Z_{rl\text{-}net}}{2000}\right) \text{ mm,}$$

but is not to be less than 50 mm

where

$Z_{rl\text{-}net}$ = net Rule section modulus, for the stiffener, in cm^3. In the case of two stiffeners connected, it need not be taken as greater than that of the smallest connected stiffener.

1.8.4 **Bracketless connections**.

1.8.4.1 Local support members, for example, longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends, in accordance with the requirements of 1.8.2 and 1.8.3.

1.8.4.2 Where alternative connections are adopted, the proposed arrangements will be specially considered.

1.8.4.3 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.8.5 **Sniped ends**.

1.8.5.1 Stiffeners with sniped ends may be used where dynamic loads are small and where the incidence of vibration is considered to be small, i.e., structure not in the stern area and structure not in the vicinity of engines or generators, provided the net thickness of plating supported by the stiffener, $t_{p\text{-}net}$, is not less than:

$$t_{p\text{-}net} = c_1 \sqrt{\left(1000 l - \frac{s}{2}\right) \frac{s\,P\,k}{1000}} \text{ mm}$$

where

l = stiffener span, in metres

s = stiffener spacing, in mm

P = design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets and method to derive the design pressure are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:

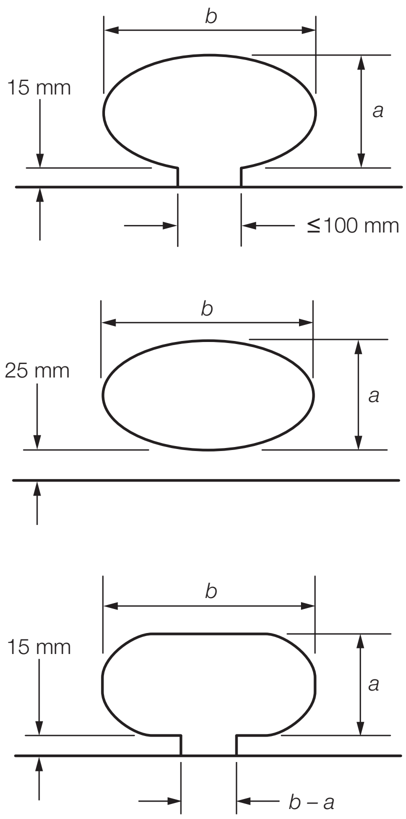
(a) Table 3.2.5 in the cargo tank region
(b) Section 3.11.2.2 in the area forward of the forward cargo tank, and in the aft end
(c) Section 4.9.1 in the machinery space

k = higher strength steel factor, as defined in Ch 1,3.1.7

c_1 = coefficient for the design load set being considered, to be taken as:
= 1,2 for acceptance criteria set AC1
= 1,1 for acceptance criteria set AC2
= 1,0 for acceptance criteria set AC3.

1.8.5.2 Bracket toes and sniped end members are, in general, to be kept within 25 mm of the adjacent member. The maximum distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Special attention is to be given to the end taper by using a sniped end of not more than 30 degrees. The depth of toe or sniped end is, generally, not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

1.8.5.3 The end attachments of non-load-bearing members may be snipe ended. The sniped end is to be not more than 30 degrees and is generally to be kept within 50 mm of the adjacent member, unless it is supported by a member on the opposite side of the plating. The depth of the toe is generally not to exceed 15 mm.



NOTE
The details shown in this Figure are for guidance and illustration only.

Fig. 3.1.10(a)
Examples of air and drain holes and scallops

1.8.6 **Air and drain holes and scallops**.

1.8.6.1 Air, drain holes, scallops and block fabrication butts are to be kept at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration measured along the length of the stiffener toward the midspan and 50 mm measured along the length in the opposite direction, *see* Fig. 3.1.10(b). In areas where the shear stress is less than 60 per cent of the allowable limit, alternative arrangements may be accepted. Openings are to be well-rounded. Fig. 3.1.10(a) shows some examples of air and drain holes and scallops. In general, the ratio of *a/b*, as defined in Fig. 3.1.10(a), is to be between 0,5 and 1,0. In fatigue-sensitive areas, further consideration may be required with respect to the details and arrangements of openings and scallops.

1.8.7 **Special requirements**.

1.8.7.1 Closely spaced scallops or drain holes, i.e., where the distance between scallops/drain holes is less than twice the width *b* as shown in Fig. 3.1.10(a), are not permitted in longitudinal strength members or within 20 per cent of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted, provided that they are of elliptical shape or equivalent to minimise stress concentration and are, in general, cut clear of the weld connection.

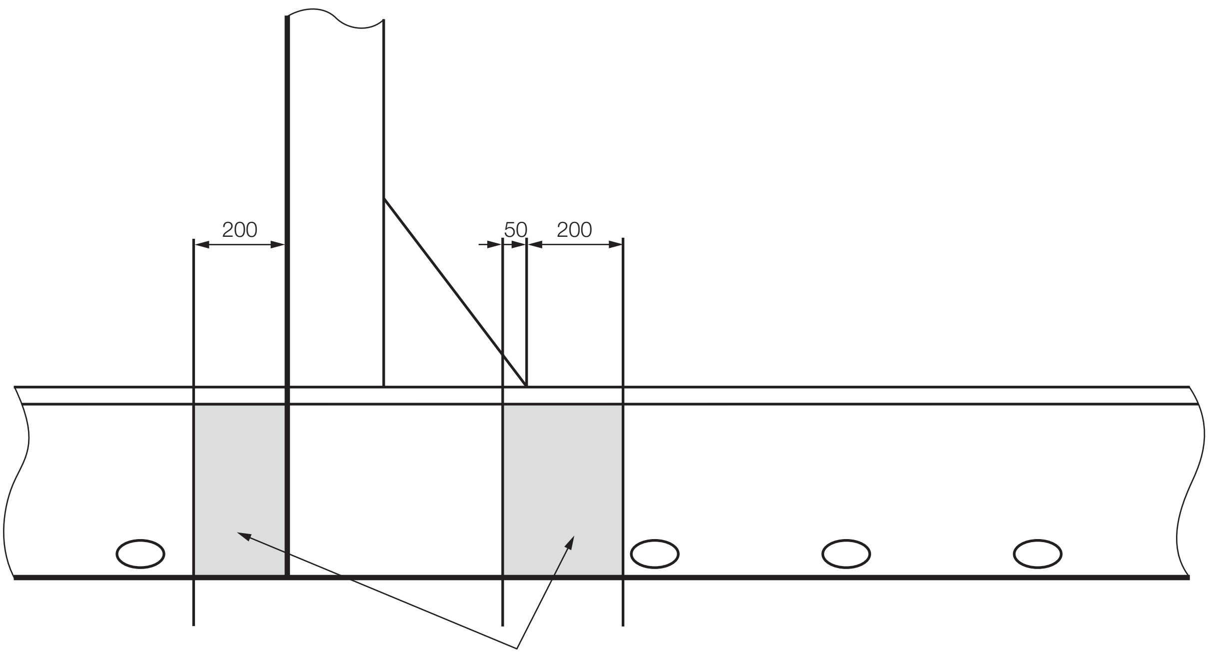


Fig. 3.1.10(b) Location of air and drain holes

1.9 Termination of primary support members

1.9.1 **General**.

1.9.1.1 Primary support members are to be arranged to ensure effective continuity of strength. Abrupt changes of depth or section are to be avoided. Primary support members in tanks are to form a continuous line of support and, wherever possible, a complete ring system.

1.9.1.2 The members are to have adequate lateral stability and web stiffening, and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well-rounded corners and are to be located considering the stress distribution and buckling strength of the panel.

1.9.2 **End connection**.

1.9.2.1 Primary support members are to be provided with adequate end fixity by brackets or equivalent structure. The design of end connections and their supporting structure is to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.9.2.2 The ends of brackets are generally to be soft-toed. The free edges of the brackets are to be stiffened. Scantlings and details are given in 1.9.3.

1.9.2.3 Where primary support members are subjected to concentrated loads, additional strengthening may be required, particularly if these are out of line with the member web.

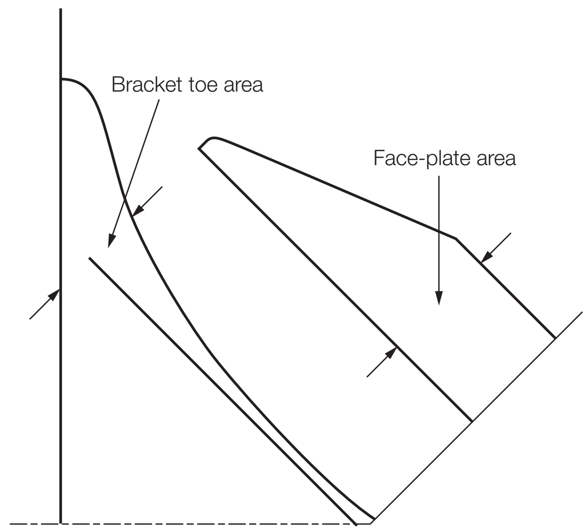
1.9.2.4 In general, ends of primary support members or connections between primary support members forming ring systems are to be provided with brackets. Bracketless connections may be applied, provided that there is adequate support of the adjoining face-plates.

1.9.3 **Brackets**.

1.9.3.1 In general, the arm lengths of brackets connecting primary support members are not to be less than the web depth of the member, and need not be taken as greater than 1,5 times the web depth. The thickness of the bracket is, in general, not to be less than that of the girder web plate.

1.9.3.2 For a ring system where the end bracket is integral with the webs of the members and the face-plate is carried continuously along the edges of the members and the bracket, the full area of the largest face-plate is to be maintained close to the mid point of the bracket and gradually tapered to the smaller face-plates. Butts in face-plates are to be kept well clear of the bracket toes.

1.9.3.3 Where a wide face-plate abuts a narrower one, the taper is generally not to be greater than 1 in 4. Where a thick face-plate abuts against a thinner one and the difference in thickness is greater than 4 mm, the taper of the thickness is not to be greater than 1 in 3.



NOTE
The details shown in this Figure are only used to illustrate items described in the text and are not intended to represent design guidance or recommendations.

Fig. 3.1.11 Bracket toe construction

1.9.3.4 Face-plates of brackets are to have a net cross-sectional area, $A_{f\text{-}net}$, which is not to be less than:

$A_{f\text{-}net}$ = $l_{bkt\text{-}edge}\, t_{bkt\text{-}net}$ cm

where

$l_{bkt\text{-}edge}$ = length of free edge of bracket, in metres. For brackets that are curved, the length of the free edge may be taken as the length of the tangent at the mid point of the free edge. If $l_{bkt\text{-}edge}$ is greater than 1,5 m, 40 per cent of the face-plate area is to be in a stiffener fitted parallel to the free edge and a maximum 0,15 m from the edge

$t_{bkt\text{-}net}$ = minimum net bracket thickness, in mm, as defined in 1.8.3.3.

1.9.4 **Bracket toes**.

1.9.4.1 The toes of brackets are not to land on unstiffened plating. Notch effects at the toes of brackets may be reduced by making the toe concave or otherwise tapering it off. In general, the toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. The end brackets of large primary support members are to be soft-toed. Where any end bracket has a face-plate, it is to be sniped and tapered at an angle not greater than 30 degrees.

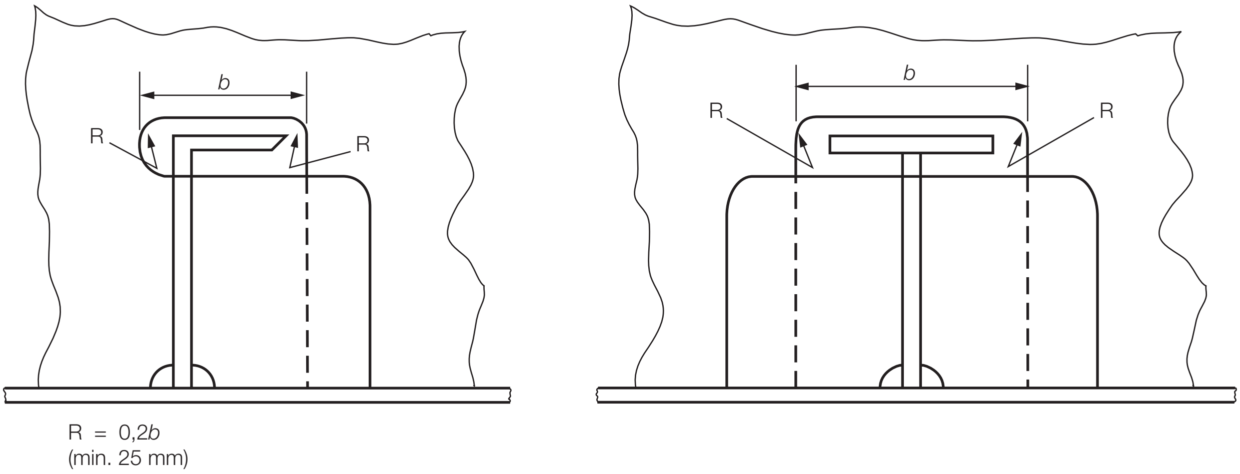


Fig. 3.1.12 Collars for cut-outs in areas of high stress

1.9.4.2 Where primary support members are constructed of higher strength steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face-plates, which are welded onto the edge of primary support member brackets, are to be carried well around the radiused bracket toe and are to incorporate a taper not greater than 1 in 3. Where sniped face-plates are welded adjacent to the edge of primary support member brackets, an adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area, measured perpendicular to the face-plate, is to be not less than 60 per cent of the full cross-sectional area of the face-plate, *see* Fig. 3.1.11.

1.10 Intersections of continuous local support members and primary support members

1.10.1 **General**.

1.10.1.1 Cut-outs for the passage of stiffeners through the web of primary support members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

1.10.1.2 Cut-outs in way of cross-tie ends and floors under bulkhead stools or in high stress areas are to be fitted with 'full' collar plates, *see* Fig. 3.1.12.

1.10.1.3 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of 1.10.3, and in areas of significant stress concentrations, e.g., in way of primary support member toes.

1.10.1.4 When, in the following locations, the calculated direct stress, σ_w, in the primary support member web stiffener according to 1.10.3.5 exceeds 80 per cent of the permissible values, a soft heel is to be provided in way of the heel of primary support member web stiffeners:

(a) connection to shell envelope longitudinals below the deep load draught, T_{sc};

(b) connection to inner bottom longitudinals.

A soft heel is not required at the intersection with watertight bulkheads, where a back bracket is fitted or where the primary support member web is welded to the stiffener face-plate. The soft heel is to have a keyhole, similar to that shown in Fig. 3.1.14(c).

1.10.2 **Details of cut-outs**.

1.10.2.1 In general, cut-outs are to have rounded corners and the corner radii, *R*, are to be as large as practicable, with a minimum of 20 per cent of the breadth, *b*, of the cut-out or 25 mm, whichever is greater, but need not be greater than 50 mm, *see* Fig. 3.1.12. Consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

1.10.3 **Connection between primary support members and intersecting stiffeners (local support members)**.

1.10.3.1 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

1.10.3.2 The total load, W, transmitted through the connection to the primary support member is given by:

$$W = P\,s\left(S - \frac{s}{2000}\right)10^{-3}\ \text{kN}$$

where

P = design pressure for the stiffener for the design load set being considered, in kN/m^2. The design load sets, method to derive the design pressure and applicable acceptance criteria set are to be taken in accordance with the following criteria, which define the acceptance criteria set to be used:
Table 3.2.5 in the cargo tank region
3.11.2.2 in the area forward of the forward cargo tank
3.11.2.2 in the aft end
4.9.1 in the machinery space
Ch 3,6 if subjected to sloshing loads
Ch 3,6 if subjected to bottom slamming loads
Ch 3,6 if subjected to bow impact loads

S = primary support member spacing, in metres

s = stiffener spacing, in mm

For stiffeners having different primary support member spacing, S, and/or different pressure, P, at each side of the primary support member, the average load for the two sides is to be applied, e.g., vertical stiffeners at transverse bulkhead.

1.10.3.3 The load, W_1, transmitted through the shear connection is to be taken as follows:
If the web stiffener is connected to the intersecting stiffener:

$$W_1 = W\left(\alpha_a + \frac{A_{1\text{-net}}}{4f_c\,A_{w\text{-net}} + A_{1\text{-net}}}\right)\ \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$$W_1 = W$$

where

W = the total load, in kN, as defined in 1.10.3.2

α_a = panel aspect ratio, not to be taken greater than 0,25
$= \dfrac{s}{1000S}$

S = primary support member spacing, in metres

s = stiffener spacing, in mm

$A_{1\text{-net}}$ = effective net shear area of the connection, to be taken as the sum of the components of the connection:
$A_{1d\text{-net}} + A_{1c\text{-net}}$ cm^2
in case of a slit type slot connections area, $A_{1\text{-net}}$, is given by:
$A_{1\text{-net}} = 2l_d\,t_{w\text{-net}}\,10^{-2}$ cm^2
in case of a typical double lug or collar plate connection area, $A_{1\text{-net}}$, is given by:
$A_{1\text{-net}} = 2f_1\,l_c\,t_{c\text{-net}}\,10^{-2}$ cm^2

$A_{1d\text{-net}}$ = net shear connection area excluding lug or collar plate, as given by the following and Fig. 3.1.13:
$A_{1d\text{-net}} = l_d\,t_{w\text{-net}}\,10^{-2}$ cm^2

l_d = length of direct connection between stiffener and primary support member web, in mm

$t_{w\text{-net}}$ = net web thickness of the primary support member, in mm

$A_{1c\text{-net}}$ = net shear connection area with lug or collar plate, given by the following and Fig. 3.1.13:
$A_{1c\text{-net}} = f_1\,l_c\,t_{c\text{-net}}\,10^{-2}$ cm^2

l_c = length of connection between lug or collar plate and primary support member, in mm

$t_{c\text{-net}}$ = net thickness of lug or collar plate, not to be taken greater than the net thickness of the adjacent primary support member web, in mm

f_1 = shear stiffness coefficient:
= 1,0 for stiffeners of symmetrical cross-section
$= \dfrac{140}{w}$ for stiffeners of asymmetrical cross-section
but is not to be taken as greater than 1,0

w = the width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Fig. 3.1.13

$A_{w\text{-net}}$ = effective net cross-sectional area of the primary support member web stiffener in way of the connection, including backing bracket where fitted, as shown in Fig. 3.1.14, in cm. If the primary support member web stiffener incorporates a soft heel ending or soft heel and soft toe ending, $A_{w\text{-net}}$ is to be measured at the throat of the connection, as shown in Fig. 3.1.14

f_c = the collar load factor defined as follows:
for intersecting stiffeners of symmetrical cross-section:
= 1,85 for $A_{w\text{-net}} \leq 14$
= 1,85 – 0,0441 ($A_{w\text{-net}}$ – 14) for 14 < $A_{w\text{-net}} \leq 31$
= 1,1 – 0,013 ($A_{w\text{-net}}$ – 31) for 31 < $A_{w\text{-net}} \leq 58$
= 0,75 for $A_{w\text{-net}} > 58$
for intersecting stiffeners of asymmetrical cross-section:

$$0{,}68 + 0{,}0172\,\frac{l_s}{A_{w\text{-net}}}$$

where

l_s = l_c for a single lug or collar plate connection to the primary support member
= l_d for a single sided direct connection to the primary support member
= mean of the connection length on both sides, i.e., in the case of a lug or collar plus a direct connection, $l_s = 0{,}5\,(l_c + l_d)$

1.10.3.4 The load, W_2, transmitted through the primary support member web stiffener is to be taken as follows:
If the web stiffener is connected to the intersecting stiffener:

$$W_2 = W\left(1 - \alpha_a - \frac{A_{1\text{-net}}}{4f_c\,A_{w\text{-net}} + A_{1\text{-net}}}\right)\ \text{kN}$$

If the web stiffener is not connected to the intersecting stiffener:

$$W_2 = 0$$

where

W = the total load, in kN, as defined in 1.10.3.2

α_a = panel aspect ratio

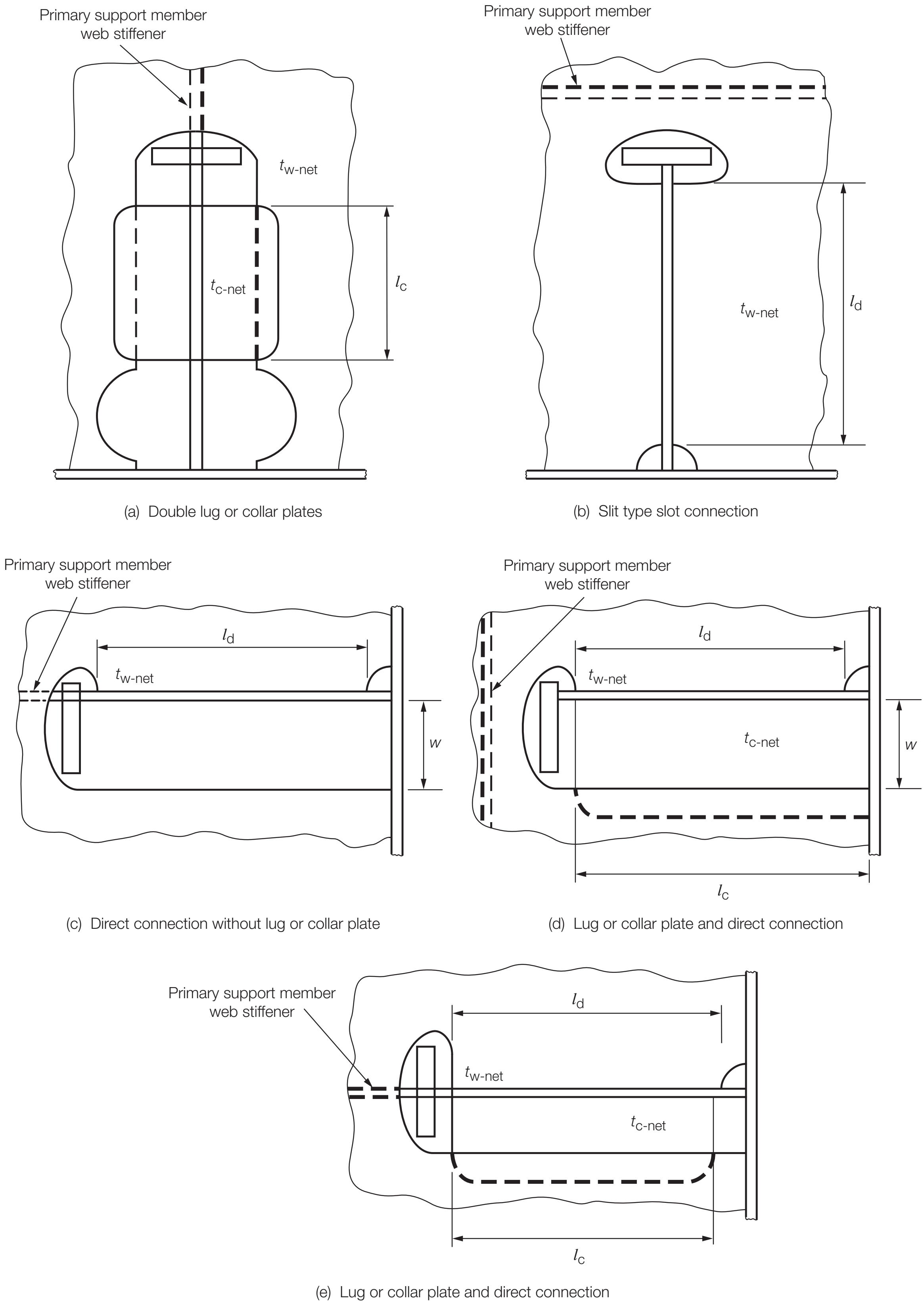
S = primary support member spacing, in metres

s = stiffener spacing, in mm

$A_{1\text{-net}}$ = effective net shear area of the connection, in cm^2, as defined in 1.10.3.3

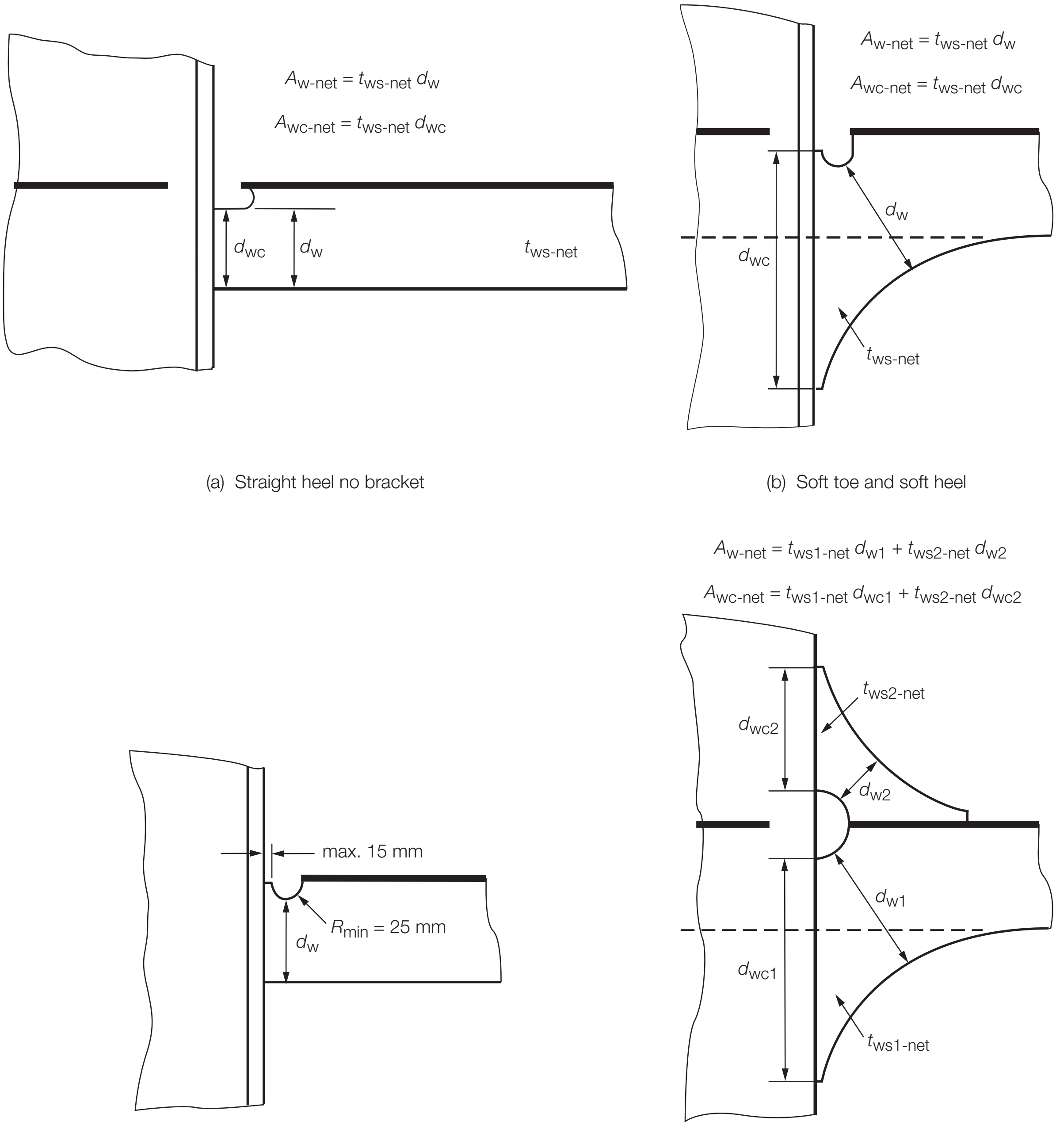
f_c = collar load factor, as defined in 1.10.3.3

$A_{w\text{-net}}$ = effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in 1.10.3.3.



NOTE
The details shown in this Figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig. 3.1.13 Symmetric and asymmetric cut-outs



where

$t_{ws\text{-}net}$, $t_{ws1\text{-}net}$ and $t_{ws2\text{-}net}$	net thickness of the primary support member web stiffener/backing bracket, in mm
d_w, d_{w1} and d_{w2}	minimum depth of the primary support member web stiffener/backing bracket, in mm
d_{wc}, d_{wc1} and d_{wc2}	length of connection between the primary support member web stiffener/backing bracket and the local support stiffener, in mm

NOTE
Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, *see* 1.10.1.4, the details shown in this Figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

Fig. 3.1.14 Primary support member web stiffener details

Table 3.1.5 Permissible stresses for connection between stiffeners and primary support members

Item	Direct stress, σ_{perm}, in N/mm^2			Shear stress, τ_{perm}, in N/mm^2		
	Acceptance criteria set, *see* 3.4.3.2			Acceptance criteria set, *see* 3.4.3.2		
	AC1	AC2	AC3	AC1	AC2	AC3
Primary support member web stiffener	$0{,}83\sigma_{yd}$, *see* Note 3	σ_{yd}	σ_{yd}	—	—	—
Primary support member web stiffener to intersecting stiffener in way of weld connection:						
double continuous fillet	$0{,}58\sigma_{yd}$ *see* Note 3	$0{,}7\sigma_{yd}$ *see* Note 3	σ_{yd}	—	—	—
partial penetration weld	$0{,}83\sigma_{yd}$ *see* Notes 2 & 3	σ_{yd} *see* Note 2	σ_{yd}	—	—	—
Primary support member stiffener to intersecting stiffener in way of lapped welding	$0{,}5\sigma_{yd}$	$0{,}6\sigma_{yd}$	σ_{yd}	—	—	—
Shear connection including lugs or collar plates:						
single sided connection	—	—	—	$0{,}71\tau_{yd}$	$0{,}85\tau_{yd}$	τ_{yd}
double sided connection	—	—	—	$0{,}83\sigma_{yd}$	τ_{yd}	τ_{yd}

Symbols

τ_{perm} = permissible shear stress, in N/mm^2

σ_{perm} = permissible direct stress, in N/mm^2

σ_{yd} = minimum specified material yield stress, in N/mm^2

$\tau_{yd} = \dfrac{\sigma_{yd}}{\sqrt{3}}$, in N/mm^2

NOTES

1. The stress computation on plate type members is to be performed on the basis of net thicknesses, whereas gross values are to be used in weld strength assessments, *see* 1.10.3.11.
2. The root face is not to be greater than one third of the gross thickness of the primary support member stiffener.
3. Allowable stresses may be increased by 5 per cent where a soft heel is provided in way of the heel of the primary support member web stiffener.

1.10.3.5 The values of $A_{w\text{-}net}$, $A_{wc\text{-}net}$ and $A_{1\text{-}net}$ are to be such that the calculated stresses satisfy the following criteria: for the connection to the primary support member web stiffener away from the weld:

$$\sigma_w \le \sigma_{perm}$$

for the connection to the primary support member web stiffener in way of the weld:

$$\sigma_{wc} \le \sigma_{perm}$$

for the shear connection to the primary support member web:

$$\tau_w \le \tau_{perm}$$

where

σ_w = direct stress in the primary support member web stiffener at the minimum bracket area away from the weld connection:

$$= \frac{10W_2}{A_{w\text{-}net}} \text{ N/mm}^2$$

σ_{wc} = direct stress in the primary support member web stiffener in way of the weld connection:

$$= \frac{10W_2}{A_{wc\text{-}net}} \text{ N/mm}^2$$

τ_w = shear stress in the shear connection to the primary support member

$$= \frac{10W_1}{A_{1\text{-}net}} \text{ N/mm}^2$$

$A_{w\text{-}net}$ = effective net cross-sectional area of the primary support member web stiffener, in cm^2, as defined in 1.10.3.3

$A_{wc\text{-}net}$ = effective net area of the web stiffener in way of the weld as shown in Fig. 3.1.14, in cm^2

$A_{1\text{-}net}$ = effective net shear area of the connection, in cm^2, as defined in 1.10.3.3

W_1 = load transmitted through the shear connection, in kN, as defined in 1.10.3.3

W_2 = load transmitted through the web stiffener, in kN, as defined in 1.10.3.4

σ_{perm} = permissible direct stress given in Table 3.1.5 for the applicable acceptance criteria, *see* 1.10.3.2, in N/mm^2

τ_{perm} = permissible shear stress given in Table 3.1.5 for the applicable acceptance criteria, *see* 1.10.3.2, in N/mm^2
when total load, W, is bottom slamming or bow impact loads, the following criteria apply in lieu of 1.10.3.3 to 1.10.3.5

$$0{,}9W \leq \frac{(A_{1\text{-net}}\,\tau_{perm} + A_{w\text{-net}}\,\sigma_{perm})}{10} \text{ kN}$$

$A_{1\text{-net}}$ = effective net shear area in cm^2 of the connection, as defined in 1.10.3.3
$A_{w\text{-net}}$ = effective net cross-sectional area in cm^2 of the primary support member web stiffener in way of the connection including backing bracket where fitted, as defined in 1.10.3.3
σ_{perm} = permissible direct stress given in Table 3.1.5 for AC3, in N/mm^2
τ_{perm} = permissible shear stress given in Table 3.1.5 for AC3, in N/mm^2.

1.10.3.6 Where a backing bracket is fitted in addition to the primary support member web stiffener, it is to be arranged on the opposite side to, and in alignment with, the web stiffener. The arm length of the bracket is to be not less than the depth of the web stiffener and its net cross-sectional area through the throat of the bracket is to be included in the calculation of $A_{w\text{-net}}$ as shown in Fig. 3.1.14.

1.10.3.7 Lapped connections of primary support member web stiffeners or tripping brackets to local support members are not permitted in the cargo tank region, e.g., lapped connections between transverse and longitudinal local support members.

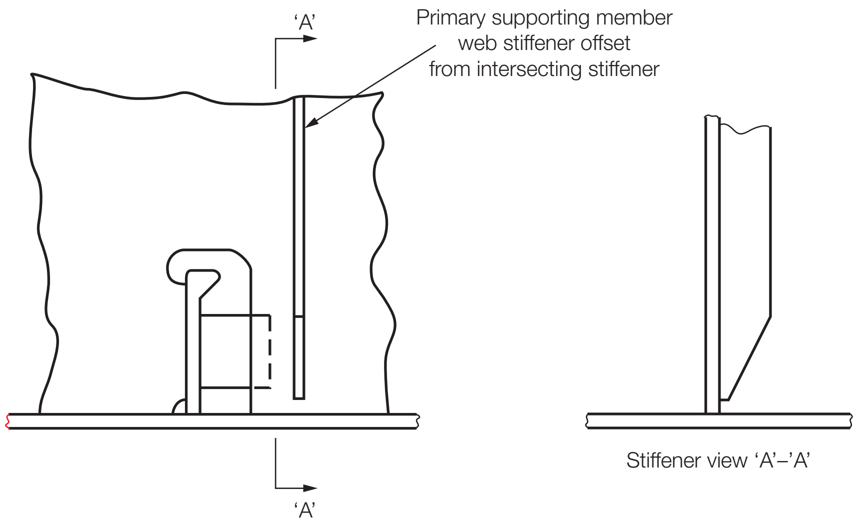


Fig. 3.1.15 Offset primary support member web stiffeners

Table 3.1.6 Weld factors for connection between stiffeners and primary support members

Item	Weld factor
Primary support member stiffener to intersecting stiffener	$0{,}6\sigma_w/\sigma_{perm}$ not to be less than 0,38
Shear connection inclusive lug or collar plate	0,38
Shear connection inclusive lug or collar plate, where the web stiffener of the primary support member is not connected to the intersection stiffener	$0{,}6\tau_w/\tau_{perm}$ not to be less than 0,44
Symbol	
τ_w = shear stress, as defined in 1.10.3.5 σ_w = direct stress, as defined in 1.10.3.5 τ_{perm} = permissible shear stress, in N/mm^2, *see* Table 3.1.5 σ_{perm} = permissible direct stress, in N/mm^2, *see* Table 3.1.5	

1.10.3.8 Fabricated stiffeners having their face-plate welded to the side of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where such sections are connected to the primary support member web stiffener, a symmetrical arrangement of connection to the transverse members is to be incorporated. This may be implemented by fitting backing brackets on the opposite side of the transverse web or bulkhead. In way of the cargo tank region, the primary support member web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

1.10.3.9 Where the web stiffener of the primary support member is parallel to the web of the intersecting stiffener, but not connected to it, the offset primary support member web stiffener may be located as shown in Fig. 3.1.15. The offset primary support member web stiffener is to be located in close proximity to the slot edge, *see also* Fig. 3.1.15. The ends of the offset web stiffeners are to be suitably tapered and softened.

1.10.3.10 Alternative arrangements will be specially considered on the basis of their ability to transmit load with equivalent effectiveness. Details of calculations made and/or testing procedures and results are to be submitted.

1.10.3.11 The size of the fillet welds is to be calculated according to Pt 4, Ch 8, based on the weld factors given in Table 3.1.6. For the welding in way of the shear connection, the size is not to be less than that required for the primary support member web plate for the location under consideration.

1.11 Openings

1.11.1 **General**.

1.11.1.1 Openings are to have well rounded corners.

1.11.1.2 Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. Examples of high stress areas include:

(a) in vertical or horizontal diaphragm plates in narrow cofferdams/double plate bulkheads within one sixth of their length from either end;
(b) in floors or double bottom girders close to their span ends;
(c) above the heads and below the heels of pillars.

Where larger openings than given by 1.11.2 or 1.11.3 are proposed, the arrangements and compensation required will be specially considered.

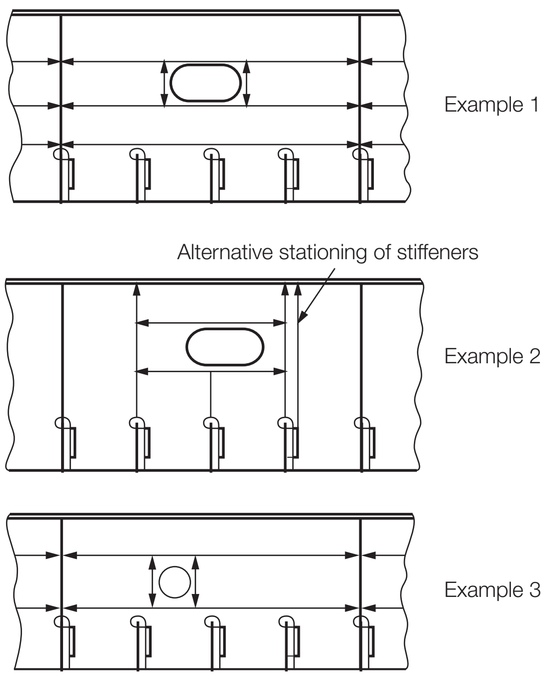


Fig. 3.1.16 Web plate with large openings

1.11.2 **Manholes and lightening holes in single skin sections not requiring reinforcement**.

1.11.2.1 Openings cut in the web with depth of opening not exceeding 25 per cent of the web depth and located so that the edges are not less than 40 per cent of the web depth from the face-plate do not generally require reinforcement. The length of opening is not to be greater than the web depth or 60 per cent of the local support member spacing, whichever is greater. The ends of the openings are to be equidistant from the corners of cut-outs for local support members.

1.11.3 **Manholes and lightening holes in double skin sections not requiring reinforcement**.

1.11.3.1 Where openings are cut in the web and are clear of high stress areas, reinforcement of these openings is not required, provided that the depth of the opening does not exceed 50 per cent of the web depth and is located so that the edges are well clear of cut-outs for the passage of local support members.

1.11.4 **Manholes and lightening holes requiring reinforcement**.

1.11.4.1 Manholes and lightening holes are to be stiffened as required by 1.11.4.2 and 1.11.4.3.

1.11.4.2 The web plate is to be stiffened at openings when the mean shear stress, as determined by application of the requirements of Chapter 3, is greater than 50 N/mm^2 for acceptance criteria set AC1 or greater than 60 N/mm^2 for acceptance criteria sets AC2 and AC3. The stiffening arrangement is to ensure buckling strength, as required by Chapter 3.

1.11.4.3 On members contributing to longitudinal strength, stiffeners are to be fitted along the free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shorter axis is less than 400 mm, and in both directions if the length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners, *see* Fig. 3.1.16.

1.12 Local reinforcement

1.12.1 **Reinforcement at knuckles**.

1.12.1.1 Whenever a knuckle in a main member (shell, longitudinal bulkhead, etc.) is arranged, adequate stiffening is to be fitted at the knuckle to transmit the transverse load. This stiffening, in the form of webs, brackets or profiles, is to be connected to the transverse members to which they are to transfer the load (in shear), *see* Fig. 3.1.17.

1.12.1.2 In general, for longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.

1.12.1.3 Generally, the distance between the knuckle and the support stiffening described in 1.12.1.1 is not to be greater than 50 mm.

1.12.2 **Reinforcement for openings and attachments associated with means of access for inspection/ maintenance purposes**.

1.12.2.1 Local reinforcement is to be provided, taking into account proper location and strength of all attachments to the hull structure for access for inspection/maintenance purposes.

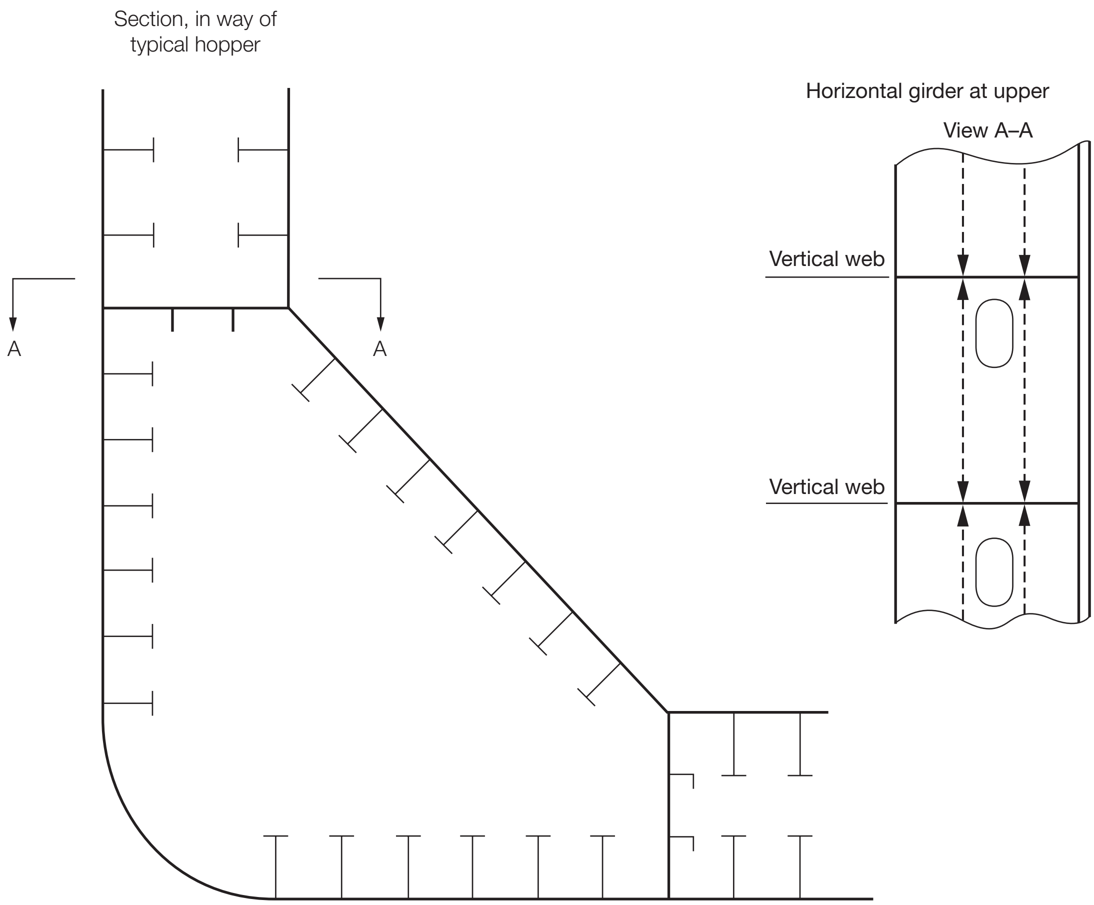


Fig. 3.1.17 Example of reinforcement at knuckles

Section 2
Cargo tank region

2.1 Symbols

2.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
B = moulded breadth, in metres
D = moulded depth, in metres
T_{SC} = deep load draught, in metres
T_{LT} = minimum design light load draught, in metres
E = modulus of elasticity, in N/mm^2
σ_{yd} = specified minimum yield stress of the material, in N/mm^2

$$\tau_{yd} = \frac{\sigma_{yd}}{\sqrt{3}} \text{ N/mm}^2$$

s = stiffener spacing, in mm
p = design pressure for the design load set being considered, in kN/m^2
g = acceleration due to gravity, 9,81 m/s^2
k = higher strength steel factor, defined in Ch 1,3.1.7.

2.2 General

2.2.1 **Application.**

2.2.1.1 The requirements of this Section apply to the hull structure within the cargo tank region of the ship unit.

2.2.2 **Evaluation of scantlings.**

2.2.2.1 Structural design details are to comply with the requirements given in 1.7 to 1.12.

2.2.2.2 The scantlings are to be assessed to ensure that the strength criteria are satisfied at all longitudinal positions, where applicable.

2.2.2.3 Local scantlings are to be increased where applicable to account for:

- local variations, such as increased spacing or increased stiffener spans;
- green sea pressure loads;
- fore and aft end strengthening requirements, *see* Sections 3 and 5;
- local deflection requirements to limit interaction between the hull structure and liquefied gas cargo containment systems where fitted; and
- in way of anti-roll chocks, anti-flotation chocks and other similar items where fitted.

2.2.2.4 Where the hull structure forms part of, or provides direct support to, a liquefied gas cargo containment system, the scantlings are to be sufficient to meet the requirements of the containment system design and the loads imposed by it. A structural analysis of the hull structure will be required using direct calculation procedures which are to be agreed with LR at as early a stage as possible.

2.2.2.5 Where a membrane type liquefied gas cargo containment system is fitted inside the hull, the scantlings of the hull providing direct support to the containment system are to comply with the requirements in this Part outlined for cargo tanks and other tanks designed for liquid filling. However, the tank pressure is to be taken as:
For static load cases:

$P_{in\text{-}tk} + P_o$

For dynamic load cases:

$P_{in\text{-}tk} + P_{in\text{-}dyn} + P_o$

where
P_o is the design vapour pressure defined in Pt 11, Ch 4,4.1.2.
For the operating and inspection/maintenance conditions the liquid density is to be taken as that of the liquefied gas cargo, *see* Table 2.1.1.
The design of membrane tanks is to comply with Pt 11, Ch 4.

Table 3.2.1 Minimum net thickness for plating and local support members in the cargo tank region

Scantling location			Net thickness (mm)
Plating	Shell	Keel plating	6,0 + 0,04L_2
		Bottom shell/bilge/side shell	4,5 + 0,03L_2
	Upper deck		4,5 + 0,02L_2
	Other structure	Hull internal tank boundaries	4,5 + 0,02L_2
		Non-tight bulkheads, bulkheads between dry spaces and other plates in general	4,5 + 0,01L_2
Local support members	Local support members on tight boundaries		3,5 + 0,015L_2
	Local support members on other structure		2,5 + 0,015L_2
Tripping brackets			5,0 + 0,015L_2

Table 3.2.2 Minimum net thickness for primary support members in cargo tank region

Scantling location	Net thickness (mm)
Bottom centreline girder	$5{,}5 + 0{,}025L_2$
Other bottom girders	$5{,}5 + 0{,}02L_2$
Bottom floors, web plates of side transverses and stringers in double hull	$5{,}0 + 0{,}015L_2$
Web and flanges of vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkhead, deck transverses (above and below upper deck) and cross ties	$5{,}5 + 0{,}015L_2$

2.2.2.6 Where an independent tank is fitted inside the hull, the scantlings of the hull structure surrounding, but not forming, part of the independent tank are to be as required for watertight boundaries. The scantlings of independent tanks are to comply with Pt 11, Ch 4.

2.2.3 **General scantling requirements.**

2.2.3.1 The hull structure is to comply with the applicable requirements of:

- hull girder longitudinal strength, *see* Section 1;
- strength against sloshing and impact loads, *see* Section 6;
- hull girder ultimate strength, *see* LR ShipRight Procedure for Ship Units;
- strength assessment (FEM), *see* LR ShipRight Procedure for Ship Units;
- fatigue strength, *see* LR ShipRight Procedure for Ship Units;
- buckling, *see* Ch 1,18.

2.2.3.2 The net section modulus, shear areas and other sectional properties of the local and primary support members are to be determined in accordance with Ch 1,12.

2.2.4 **Minimum thickness for plating and local support members.**

2.2.4.1 The thickness of plating and stiffeners in the cargo tank region is to comply with the appropriate minimum thickness requirements given in Table 3.2.1.

2.2.5 **Minimum thickness for primary support members.**

2.2.5.1 The thickness of web plating and face plating of primary support members in the cargo tank region is to comply with the appropriate minimum thickness requirements given in Table 3.2.2.

2.3 Hull envelope plating

2.3.1 **Keel plating.**

2.3.1.1 Keel plating is to extend over the flat of bottom for the complete length of the ship unit. The breadth, b_{kl}, is not to be less than:

$b_{kl} = 800 + 5L_2$ mm.

2.3.1.2 The thickness of the keel plating is to comply with the requirements given in 2.3.2.

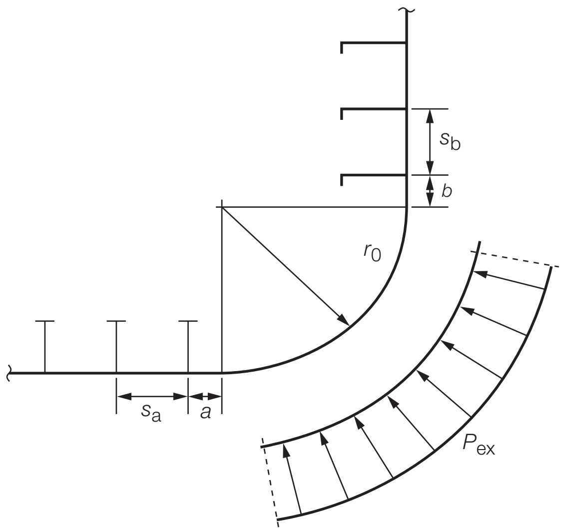


Fig. 3.2.1 Unstiffened bilge plating

2.3.2 **Bottom shell plating.**

2.3.2.1 The thickness of the bottom shell plating is to comply with the requirements in Table 3.2.4.

2.3.3 **Bilge plating.**

2.3.3.1 The thickness of bilge plating is not to be less than that required for the adjacent bottom shell, *see* 2.3.2.1, or adjacent side shell plating, *see* 2.3.4.1, whichever is the greater.

2.3.3.2 The net thickness of bilge plating, t_{net}, without longitudinal stiffening is not to be less than:

$$t_{net} = \frac{\sqrt[3]{r^2\, S_t\, P_{ex}}}{100} \quad \text{mm}$$

where

P_{ex} = design sea pressure from Table 3.2.7 calculated at the lower turn of bilge, in kN/m^2
r = effective bilge radius
= $r_0 + 0{,}5\,(a + b)$ mm
r_0 = radius of curvature, in mm, *see* Fig. 3.2.1
S_t = distance between transverse stiffeners, webs or bilge brackets, in metres
a = distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, *see* Fig. 3.2.1 and 2.4.1.2. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero
b = distance between the upper turn of bilge and the lowest side longitudinal, in mm, *see* Fig. 3.2.1 and 2.4.1.2. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero

Where the plate seam is located in the flat plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to extend to the adjacent plate above the bilge, provided that the plate seam is not more than $S_b/4$ below the lowest side longitudinal. Similarly, for flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be applied, provided that the plate seam is not more than $S_a/4$ beyond the outboard bottom longitudinal. Regularly longitudinally-stiffened bilge plating is to be assessed as a stiffened plate. The bilge keel is not considered as 'longitudinal stiffening' for the application of this requirement.

2.3.3.3 Where bilge longitudinals are omitted, the bilge plate thickness outside 0,4*L* amidships will be considered in relation to the support derived from the hull form and internal stiffening arrangements. In general, outside 0,4*L* amidships the bilge plate scantlings and arrangement are to comply with the requirements of ordinary side or bottom shell plating in the same region. Consideration is to be given where there is increased loading in the forward region.

2.3.4 **Side shell plating.**

2.3.4.1 The thickness of the side shell plating is to comply with the requirements in Table 3.2.4.

2.3.4.2 The net thickness, t_{net}, of the side plating within the range as specified in 2.3.4.3 is not to be less than:

$$t_{net} = 26 \left(\frac{s}{1000} + 0{,}7\right)\left(\frac{BT_{SC}}{\sigma_{yd}^{2}}\right)^{0{,}25} \quad \text{mm.}$$

2.3.4.3 The thickness in 2.3.4.2 is to be applied to the following extent of the side shell plating, *see* Fig. 3.2.2:

(a) longitudinal extent:
- between a section aft of amidships where the breadth at the waterline exceeds 0,9*B*, and a section forward of amidships where the breadth at the waterline exceeds 0,6*B*.

(b) vertical extent:
- between 300 mm below the minimum design waterline at the light load draught, T_{LT}, amidships to 0,25T_{SC} or 2,2 m, whichever is greater, above the draught T_{SC}.

2.3.5 **Sheerstrake.**

2.3.5.1 The sheerstrake is to comply with the requirements in 2.3.4.

2.3.5.2 The welding of deck fittings to rounded sheer-strakes is to be avoided within 0,6*L* of amidships.

2.3.5.3 Where the sheerstrake extends above the deck stringer plate, the top edge of the sheerstrake is to be kept free from notches and isolated welded fittings, and is to be smooth with rounded edges. Grinding may be required if the cutting surface is not smooth. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

2.3.6 **Deck plating.**

2.3.6.1 The thickness of the deck plating is to comply with the requirements given in Table 3.2.4.

2.4 Hull envelope framing

2.4.1 **General.**

2.4.1.1 The bottom shell, inner bottom and deck are to be longitudinally framed in the cargo tank region. The side shell, inner hull bulkheads and longitudinal bulkheads are generally to be longitudinally framed. Suitable alternatives which take account of resistance to buckling will be specially considered.

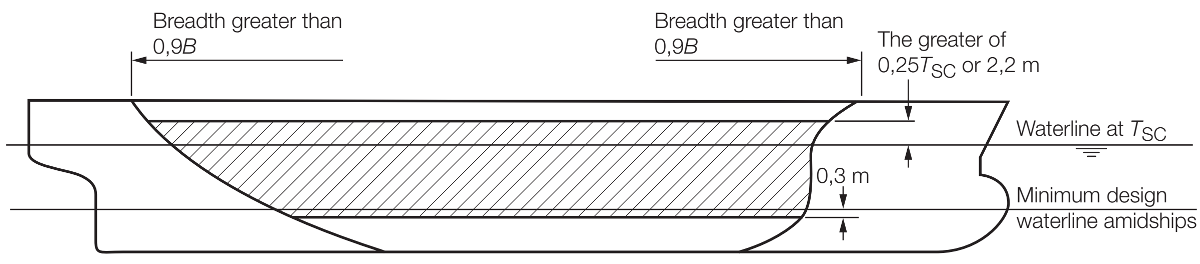


Fig. 3.2.2 Extent of side shell plating

2.4.1.2 Where longitudinals are omitted in way of the bilge, a longitudinal is to be fitted at the bottom and at the side, close to the position where the curvature of the bilge plate starts. The distance between the lower turn of bilge and the outermost bottom longitudinal, a, is generally not to be greater than one third of the spacing between the two outermost bottom longitudinals, s_a. Similarly, the distance between the upper turn of the bilge and the lowest side longitudinal, b, is generally not to be greater than one third of the spacing between the two lowest side longitudinals, s_b. *See* Fig. 3.2.1.

2.4.2 **Scantling criteria.**

2.4.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements given in Tables 3.2.5 and 3.2.6.

2.5 Inner bottom

2.5.1 **Inner bottom plating.**

2.5.1.1 The thickness of the inner bottom plating is to comply with the requirements given in Table 3.2.4.

2.5.1.2 In way of a welded hopper knuckle, the inner bottom is to be scarphed to ensure adequate load transmission to surrounding structure and reduce stress concentrations.

2.5.1.3 In way of corrugated bulkhead stools, where fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom.

2.5.2 **Inner bottom longitudinals.**

2.5.2.1 The section modulus and web plate thickness of the inner bottom longitudinals are to comply with the requirements given in Tables 3.2.5 and 3.2.6.

2.6 Bulkheads

2.6.1 **General.**

2.6.1.1 The inner hull and longitudinal bulkheads are generally to be longitudinally framed, and plane. Corrugated bulkheads are to comply with the requirements given in 2.6.6.

2.6.1.2 Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

2.6.2 **Longitudinal tank boundary bulkhead plating.**

2.6.2.1 The thickness of the longitudinal tank boundary bulkhead plating is to comply with the requirements given in Table 3.2.4.

2.6.2.2 Inner hull and longitudinal bulkheads are to extend as far forward and aft as practicable and are to be effectively scarphed into the adjoining structure.

2.6.3 **Hopper side structure.**

2.6.3.1 Knuckles in the hopper tank plating are to be supported by side girders and stringers, or by a deep longitudinal.

2.6.4 **Transverse tank boundary bulkhead plating.**

2.6.4.1 The thickness of the transverse tank boundary bulkhead plating is to comply with the requirements given in Table 3.2.4.

2.6.5 **Tank boundary bulkhead stiffeners.**

2.6.5.1 The section modulus and web thickness of stiffeners on longitudinal or transverse tank boundary bulkheads are to comply with the requirements given in Tables 3.2.5 and 3.2.6.

2.6.6 **Corrugated bulkheads.**

2.6.6.1 In general, corrugated bulkheads are to be designed with the corrugation angles, ϕ, between 55° and 90°, *see* Fig. 3.2.3.

2.6.6.2 The global strength of corrugated bulkheads, lower stools and upper stools, where fitted, and attachments to surrounding structures are to be verified with the cargo tank FEM model, in accordance with the LR ShipRight Procedure for Ship Units, in the midship region. The global strength of corrugated bulkheads outside of midship region is to be considered, based on results from the cargo tank FEM model and using the appropriate pressure for the bulkhead being considered. Additional FEM analysis of cargo tank bulkheads forward and aft of the midship region may be necessary if the bulkhead geometry, structural details and support arrangement details differ significantly from bulkheads within the mid cargo tank region.

2.6.6.3 The net thicknesses, t_{net}, of the web and flange plates of corrugated bulkheads are to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by

$$t_{net} = 0{,}0158 b_p \sqrt{\frac{|P|}{C_a \sigma_{yd}}} \text{ mm}$$

where

b_p = breadth of plate:
= b_f for flange plating, in mm, *see* Fig. 3.2.3
= b_w for web plating, in mm, *see* Fig. 3.2.3

C_a = permissible bending stress coefficient
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2
= 1,0 for acceptance criteria set AC3.

2.6.6.4 Where the corrugated bulkhead is built with flange and web plate of different thickness, the thicker net plating thickness, $t_{m\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by:

$$t_{m-net} = \sqrt{\frac{0{,}0005 b_p^2\,|P|}{C_a\,\sigma_{yd}} - t_{n\text{-}net}^2} \quad \text{mm}$$

where

$t_{n\text{-}net}$ = net thickness of the thinner plating, either flange or web, in mm

b_p = breadth of thicker plate, either flange or web, in mm

C_a = permissible bending stress coefficient
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2
= 1,0 for acceptance criteria set AC3.

2.6.7 **Vertically corrugated bulkheads.**

2.6.7.1 In addition to the requirements of 2.6.6, vertically corrugated bulkheads are also to comply with the following requirements.

2.6.7.2 The net plate thicknesses as required by 2.6.7.5 and 2.6.7.6 are to be maintained for two thirds of the corrugation length, l_{cg}, from the lower end, where l_{cg} is as defined in 2.6.7.3. Above that, the net plate thickness may be reduced by 20 per cent.

2.6.7.3 Where a lower stool is fitted, the net web plating thickness of the lower 15 per cent of the corrugation, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets from Table 3.2.7.

$$t_{w-net} = \frac{1000|Q_{cg}|}{d_{cg}\,C_{t\text{-}cg}\,\tau_{yd}} \quad \text{mm}$$

where

Q_{cg} = design shear force imposed on the web plating at the lower end of the corrugation

$$= \frac{s_{cg}\,l_{cg}\,|3P_l + P_u|}{8000} \quad \text{kN}$$

P_l = design pressure for the design load set being considered, calculated at the lower end of the corrugation, in kN/m²

P_u = design pressure for the design load set being considered, calculated at the upper end of the corrugation, in kN/m²

s_{cg} = spacing of corrugation, in mm, *see* Fig. 3.2.3

l_{cg} = length of corrugation, which is defined as the distance between the lower stool and the upper stool or the upper end where no upper stool is fitted, in metres, *see* Fig. 3.2.3

d_{cg} = depth of corrugation, in mm, *see* 2.6.7.4 and Fig. 3.2.3

$C_{t\text{-}cg}$ = permissible shear stress coefficient
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2
= 1,0 for acceptance criteria set AC3.

2.6.7.4 The depth of the corrugation, d_{cg}, is not to be less than:

$$d_{cg} = \frac{1000 l_{cg}}{15} \quad \text{mm}$$

where

l_{cg} = length of corrugation, defined as the distance between the lower stool (or inner bottom if no lower stool is fitted) and the upper stool (or upper end if no upper stool is fitted), in metres, *see* Fig. 3.2.3.

2.6.7.5 Where a lower stool is fitted, the net thickness of the lower two thirds of the flanges of corrugated bulkheads, $t_{f\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7.

$$t_{f-net} = \frac{0{,}00657 b_f\,\sqrt{\sigma_{bdg\text{-}max}}}{C_f} \quad \text{mm}$$

where

$\sigma_{bdg\text{-}max}$ = maximum vertical bending stress in the flange. The bending stress is to be calculated at the lower end and at the midspan of the corrugation length

$$= \frac{1000 M_{cg}}{Z_{cg\text{-}act\text{-}net}} \quad \text{N/mm}^2$$

M_{cg} = as defined in 2.6.7.6

$Z_{cg\text{-}act\text{-}net}$ = actual net section modulus at the lower end and at the mid length of the corrugation, in cm³

b_f = breadth of flange plating, in mm, *see* Fig. 3.2.3

b_w = breadth of web plating, in mm, *see* Fig. 3.2.3

C_f = coefficient

$$= 7{,}65 - 0{,}26\left(\frac{b_w}{b_f}\right)^2$$

2.6.7.6 Where a lower stool is fitted, the net section modulus at the lower and upper ends and at the mid length of the corrugation, $Z_{cg\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7.

$$Z_{cg-net} = \frac{1000 M_{cg}}{C_{s\text{-}cg}\,\sigma_{yd}} \quad \text{cm}^3$$

where

$$M_{cg} = \frac{C_i\,|P|\,s_{cg}\,l_o^2}{12\,000} \quad \text{kNm}$$

$$P = \frac{P_u + P_l}{2} \quad \text{kN/m}^2$$

P_l, P_u = design pressure for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m²:
for transverse corrugated bulkheads, the pressures are to be calculated at a section located at $b_{tk}/2$ from the longitudinal bulkheads of each tank
for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e., the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead

b_{tk} = maximum breadth of tank under consideration measured at the bulkhead, in metres

s_{cg} = spacing of corrugation, in mm, *see* Fig. 3.2.3

l_o = effective bending span of the corrugation, measured from the mid depth of the lower stool to the mid depth of the upper stool, or upper end where no upper stool is fitted, in metres, *see* Fig. 3.2.3

l_{cg} = length of corrugation, defined as the distance between the lower stool and the upper stool, or the upper end where no upper stool is fitted, in metres, *see* Fig. 3.2.3

C_i = the relevant bending moment coefficients, as given in Table 3.2.3

$C_{s\text{-}cg}$ = permissible bending stress coefficient at middle of the corrugation length, l_{cg}
= c_e, but not to be taken as greater than 0,75 for acceptance criteria set AC1
= c_e, but not to be taken as greater than 0,90 for acceptance criteria set AC2
= c_e, but not to be taken as greater than 1,0 for acceptance criteria set AC3
at the lower and upper ends of corrugation length, l_{cg}
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2
= 1,0 for acceptance criteria set AC3

$$c_e = \frac{2,25}{\beta} - \frac{1,25}{\beta^2} \qquad \text{for } \beta \geq 1,25$$
$$= 1,0 \qquad \text{for } \beta < 1,25$$

$$\beta = \frac{b_f}{t_{f\text{-}net}} \sqrt{\frac{\sigma_{yd}}{E}}$$

b_f = breadth of flange plating, in mm, *see* Fig. 3.2.3

$t_{f\text{-}net}$ = net thickness of the corrugation flange, in mm.

2.6.7.7 For tanks with effective sloshing breadth, b_{slh}, greater than 0,56*B* or effective sloshing length l_{slh}, greater than 0,13*L*, additional sloshing analysis is to be carried out to assess the section modulus of the unit corrugation.

Table 3.2.3 Values of C_i

Bulkhead	At lower end of l_{cg}	At mid length of l_{cg}	At upper end of l_{cg}
Transverse bulkhead	C_1	C_{m1}	$0{,}80C_{m1}$
Longitudinal bulkhead	C_3	C_{m3}	$0{,}65C_{m3}$

where

$C_1 = a_1 + b_1 \sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0,60

$a_1 = 0{,}95 - \dfrac{0{,}41}{R_{bt}}$

$b_1 = -0{,}20 + \dfrac{0{,}078}{R_{bt}}$

$C_{m1} = a_{m1} + b_{m1} \sqrt{\dfrac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0,55

$a_{m1} = 0{,}63 + \dfrac{0{,}25}{R_{bt}}$

$b_{m1} = -0{,}25 - \dfrac{0{,}11}{R_{bt}}$

$C_3 = a_3 + b_3 \sqrt{\dfrac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0,60

$a_3 = 0{,}86 - \dfrac{0{,}35}{R_{bl}}$

$b_3 = -0{,}17 + \dfrac{0{,}10}{R_{bl}}$

$C_{m3} = a_{m3} + b_{m3} \sqrt{\dfrac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0,55

$a_{m3} = 0{,}32 + \dfrac{0{,}24}{R_{bl}}$

$b_{m3} = -0{,}12 - \dfrac{0{,}10}{R_{bl}}$

$R_{bt} = \dfrac{A_{bt}}{b_{ib}}\left(1 + \dfrac{l_{ib}}{b_{ib}}\right)\left(1 + \dfrac{b_{av\text{-}t}}{h_{st}}\right)$ for transverse bulkheads

$R_{bl} = \dfrac{A_{bl}}{l_{ib}}\left(1 + \dfrac{l_{ib}}{b_{ib}}\right)\left(1 + \dfrac{b_{av\text{-}l}}{h_{sl}}\right)$ for longitudinal bulkheads

A_{dt} = cross-sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m^2
= 0 if no upper stool is fitted

A_{dl} = cross-sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m^2
= 0 if no upper stool is fitted

A_{bt} = cross-sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m^2

A_{bl} = cross-sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m^2

$b_{av\text{-}t}$ = average width of transverse bulkhead lower stool, in metres. *See* Fig. 3.2.3

$b_{av\text{-}l}$ = average width of longitudinal bulkhead lower stool, in metres. *See* Fig. 3.2.3

h_{st} = height of transverse bulkhead lower stool, in metres. *See* Fig. 3.2.3

h_{sl} = height of longitudinal bulkhead lower stool, in metres. *See* Fig. 3.2.3

b_{ib} = breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in metres. *See* Fig. 3.2.3

b_{dk} = breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in metres. *See* Fig. 3.2.3

l_{ib} = length of cargo tank at the inner bottom level between transverse lower stools, in metres. *See* Fig. 3.2.3

l_{dk} = length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in metres. *See* Fig. 3.2.3

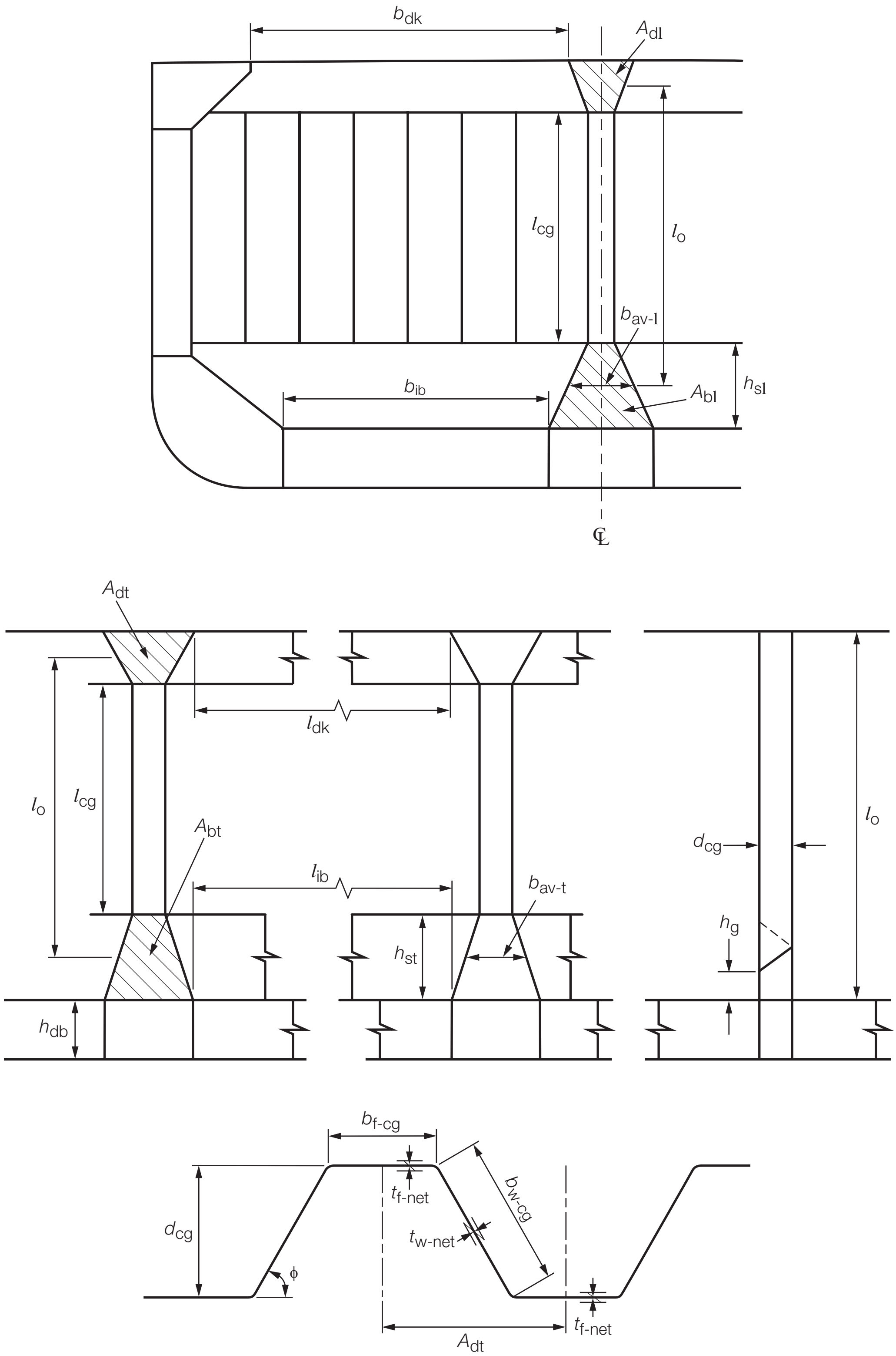


Fig. 3.2.3 Definition of parameters for corrugated bulkhead (units with longitudinal bulkhead at centreline)

Table 3.2.4 Thickness requirements for plating

The minimum net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets, as given in Table 3.2.7, and given by

$$t_{net} = 0{,}0158\alpha_p\, s \sqrt{\frac{|P|}{C_a\,\sigma_{yd}}} \quad \text{mm}$$

where

α_p = correction factor for the panel aspect ratio

$= 1{,}2 - \dfrac{s}{2100 l_p}$ but is not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in metres

C_a = permissible bending stress coefficient for the design load set being considered

$= \beta_a - \alpha_a \dfrac{|\sigma_{hg}|}{\sigma_{yd}}$ but not to be taken greater than C_{a-max}

Acceptance criteria set	Structural member		β_a	α_a	C_{a-max}
AC1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely or vertically stiffened plating	0,9	1,0	0,8
	Other members		0,8	0	0,8
AC2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely or vertically stiffened plating	1,05	1,0	0,95
	Other members, including watertight boundary plating		1,0	0	1,0
AC3	All members		1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the load calculation point

$= \left(\dfrac{(z - z_{NA-net50})\, M_{v-total}}{I_{v-net50}} - \dfrac{y\, M_{h-total}}{I_{h-net50}}\right) 10^{-3}$ N/mm^2

$M_{v-total}$ = design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw-perm}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}

$M_{h-total}$ = design horizontal bending moment at the longitudinal position under consideration for the design load set being considered, in kNm

$I_{v-net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

$I_{h-net50}$ = net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4

y = transverse coordinate of load calculation point, in metres

z = vertical coordinate of the load calculation point under consideration, in metres

$z_{NA-net50}$ = distance from the baseline to the horizontal neutral axis, in metres

Table 3.2.5 Section modulus requirements for stiffeners

The minimum net section modulus, Z_{net}, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by:

$$Z_{net} = \frac{|P|\, s l_{bdg}^{2}}{f_{bdg}\, C_s\, \sigma_{yd}} \quad \text{cm}^3$$

where

f_{bdg} = bending moment factor:
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:
= 12 for horizontal stiffeners
= 10 for vertical stiffeners
for stiffeners with reduced end fixity, *see* Table 3.7.2

l_{bdg} = effective bending span, in metres

C_s = permissible bending stress coefficient for the design load set being considered, to be taken as:

Sign of hull girder bending stress, σ_{hg}	Side pressure acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{\|\sigma_{hg}\|}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (-ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-}max}$
Compression (-ve)	Stiffener side	

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinal strength member	0,85	1,0	0,75
	Transverse or vertical member	0,75	0	0,75
AC2	Longitudinal strength member	1,0	1,0	0,9
	Transverse or vertical member	0,9	0	0,9
	Watertight boundary stiffeners	0,9	0	0,9
AC3	All members	1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the reference point

$$= \left(\frac{(z - z_{NA\text{-}net50})\, M_{v\text{-}total}}{I_{v\text{-}net50}} - \frac{y\, M_{h\text{-}total}}{I_{h\text{-}net50}}\right) \quad \text{N/mm}^2$$

$M_{v\text{-}total}$ = design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm. $M_{v\text{-}total}$ is to be calculated in accordance with Table 2.6.1 in Chapter 2 using the permissible hogging or sagging still water bending moment, $M_{sw\text{-}perm}$, to be taken as:

Stiffener location	$M_{sw\text{-}perm}$	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Sagging SWBM

$M_{h\text{-}total}$ = design horizontal bending moment at longitudinal position under consideration for the design load set being considered, in kNm
$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4
$I_{h\text{-}net50}$ = net horizontal hull girder moment of inertia, at the longitudinal position being considered, in m^4
y = transverse coordinate of the reference point, in metres
z = vertical coordinate of the reference point, in metres
$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

Table 3.2.6 Web thickness requirements for stiffeners

The minimum net web thickness, $t_{w\text{-}net}$, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and given by

$$t_{w-net} = \frac{f_{shr}\,|P|\,s\,l_{shr}}{d_{shr}\,C_t\,\tau_{yd}} \text{ mm}$$

where

f_{shr} = shear force distribution factor:
for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having as fixed ends:
= 0,5 for horizontal stiffeners
= 0,7 for vertical stiffeners
for stiffeners with reduced end fixity, *see* Table 3.7.2

d_{shr} = effective shear depth, in mm

C_t = permissible shear stress coefficient for the design load set being considered, to be taken as
= 0,75 for acceptance criteria set AC1
= 0,90 for acceptance criteria set AC2
= 1,0 for acceptance criteria set AC3

2.6.7.8 For ship units with a moulded depth equal to or greater than 16 m, a lower stool is to be fitted in compliance with the following requirements:

(a) general:
- the height and depth are not to be less than the depth of the corrugation;
- the lower stool is to be fitted in line with the double bottom floors or girders;
- the side stiffeners and vertical webs (diaphragms) within the stool structure are to align with the structure below, as far as is practicable, to provide appropriate load transmission to structures within the double bottom.

(b) stool top plating:
- the net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation;
- the extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.

(c) stool side plating and internal structure:
- within the region of the corrugation depth from the stool top plate, the net thickness of the stool side plate is not to be less than 90 per cent of that required by 2.6.7.2 for the corrugated bulkhead flange at the lower end and is to be of at least the same material yield strength;
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners is not to be less than that required by 2.6.2, 2.6.4 and 2.6.5 for transverse or longitudinal bulkhead plating and stiffeners;
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool;
- continuity is to be maintained, as far as practicable, between the corrugation web and supporting brackets inside the stool. The bracket net thickness is not to be less than 80 per cent of the required thickness of the corrugation webs and is to be of at least the same material yield strength;
- scallops in the diaphragms in way of the connections of the stool sides to the inner bottom and to the stool top plate are not permitted.

2.6.7.9 For ship units with a moulded depth less than 16 m, the lower stool may be eliminated, provided the following requirements are complied with:

(a) General:
- Double bottom floors or girders are to be fitted in line with the corrugation flanges for transverse or longitudinal bulkheads, respectively;
- brackets/carlings are to be fitted below the inner bottom and hopper tank in line with corrugation webs. Where this is not practicable, gusset plates with shedder plates are to be fitted, *see* item (c) below and Fig. 3.2.3;
- the corrugated bulkhead and its supporting structure are to be assessed by Finite Element (FE) analysis, in accordance with the LR ShipRight Procedure for Ship Units. In addition, the local scantlings requirements of 2.6.6.3 and 2.6.6.4 and the minimum corrugation depth requirement of 2.6.7.4 are to be applied.

(b) Inner bottom and hopper tank plating:
- The inner bottom and hopper tank in way of the corrugation are to be of at least the same material yield strength as the attached corrugation.

(c) Supporting structure:
- Within the region of the corrugation depth below the inner bottom, the net thickness of the supporting double bottom floors or girders is not to be less than the net thickness of the corrugated bulkhead flange at the lower end, and is to be of at least the same material yield strength;
- the upper ends of vertical stiffeners on supporting double bottom floors or girders are to be bracketed to adjacent structure;
- brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0,5 times the corrugation depth and a net thickness not less than 80 per cent of the net thickness of the corrugation webs and are to be of at least the same material yield strength;

- cut-outs for stiffeners in way of supporting double bottom floors and girders in line with corrugation flanges are to be fitted with full collar plates;
- where support is provided by gussets with shedder plates, the height of the gusset plate, *see* h_g in Fig. 3.2.3, is to be at least equal to the corrugation depth, and gussets with shedder plates are to be arranged in every corrugation. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates are not to be less than 100 per cent and 80 per cent, respectively, of the net thickness of the corrugation flanges and are to be of at least the same material yield strength. *See also* 2.6.7.11;
- scallops in brackets, gusset plates and shedder plates in way of the connections to the inner bottom or corrugation flange and web are not permitted.

2.6.7.10 In general, an upper stool is to be fitted in compliance with the following requirements:

(a) General:

- where no upper stool is fitted, finite element analysis is to be carried out in accordance with the LR ShipRight Procedure for Ship Units to demonstrate the adequacy of the details and arrangements of the bulkhead support structure to the upper deck structure;
- side stiffeners and vertical webs (diaphragms) within the stool structure are to align with adjoining structure to provide for appropriate load transmission;
- brackets are to be arranged in the intersections between the upper stool and the structure on deck.

(b) Stool bottom plating:

- the net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead, and is to be of at least the same material yield strength as the attached corrugation;
- the extension of the bottom plate beyond the corrugation is not to be less than the attached as-built flange thickness of the corrugation.

(c) Stool side plating and internal structure:

- within the region of the corrugation depth above the stool bottom plate, the net thickness of the stool side plate is to be not less than 80 per cent of that required by 2.6.7.2 for the corrugated bulkhead flange at the upper end, where the same material is used. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors (k);
- the net thickness of the stool side plating and the net section modulus of the stool side stiffeners are not to be less than that required by 2.6.2, 2.6.4 and 2.6.5 for the transverse or longitudinal bulkhead plating and stiffeners;
- the ends of stool side vertical stiffeners are to be attached to brackets at the upper and lower ends of the stool;
- scallops in the diaphragms in way of the connections of the stool sides to the deck and to the stool bottom plate are not permitted.

2.6.7.11 Where gussets with shedder plates, or shedder plates (slanting plates), are fitted at the end connection of the corrugation to the lower stool or the inner bottom, appropriate means are to be provided to prevent the possibility of gas pockets being formed by these plates.

2.6.8 **Non-tight bulkheads.**

2.6.8.1 Non-tight bulkheads (wash bulkheads) are to be in line with transverse webs, bulkheads or similar structures. They are to be of plane construction, horizontally or vertically stiffened, and are to comply with the sloshing requirements given in the LR ShipRight Procedure for Ship Units. In general, openings in the non-tight bulkheads are to have generous radii and their aggregate area is not to be less than 10 per cent of the area of the bulkhead.

2.7 Primary support members

2.7.1 **General.**

2.7.1.1 The scantlings of a primary support member are to comply with the minimum requirements of 2.2.5.

2.7.1.2 The shear area of a primary support member is, in general, to comply with the requirements of 7.3.3.5 when idealised as a simple beam.

2.7.1.3 The scantlings of all primary support members are to be verified by the Finite Element (FE) cargo tank structural analysis defined in the LR ShipRight Procedure for Ship Units.

2.7.1.4 Primary support members are to be provided with adequate end fixity and in general be arranged in one plane to form continuous transverse rings.

2.7.1.5 Primary support members are to have adequate lateral stability and the webs stiffened in accordance with buckling requirements from Ch 1,18.

2.7.1.6 Primary support members that have open slots for stiffeners are to have a depth not less than 2,5 times the depth of the slots.

Table 3.2.7 **Design load sets for plating and local support members** (*see continuation*)

	Structural member		Space type	Operation on site			Inspection/maintenance			Transit			Flooded		
				Draught	S	S+D	Draught	S	S+D	Draught	S	S+D	Draught	S	S+D
					Load	Load		Load	Load		Load	Load		Load	Load
EXTERNAL MEMBERS	Acceptance criteria				AC1	AC2		AC1	AC2		AC1	AC2		AC2	AC3
	Exposed deck	Space above deck	Green sea	Deep load		P_{ex}	Deep load		P_{ex}	Deep load		P_{ex}	Flooded		P_{ex}
		Space below deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces												
	Bilge, side shell, sheerstrake	External sea	Sea water	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Flooded	P_{ex}	P_{ex}
		Inboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces												
	Keel, bottom shell	External sea	Sea water	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Deep load	P_{ex}	P_{ex}	Flooded	P_{ex}	P_{ex}
		Space above the panel	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}			
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}						
			Dry spaces	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}			

Table 3.2.7 Design load sets for plating and local support members (*continued*)

	Structural member		Space type	Operation on site			Inspection/maintenance			Transit			Flooded		
				Draught	S Load	S+D Load	Draught	S Load	S+D Load	Draught	S Load	S+D Load	Draught	S Load	S+D Load
INTERNAL MEMBERS	Acceptance criteria				AC1	AC2		AC1	AC2		AC1	AC2		AC2	AC3
	Inner decks, inner bottom tanktops	Space above deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Light load Deep load	P_{dk}	P_{dk}	Flooded	$P_{dk} + P_{in}$	$P_{dk} + P_{in}$
		Space below deck	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}
	Bilge, side shell, sheerstrake	Outboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}
		Inboard space	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}

Table 3.2.7 Design load sets for plating and local support members (*continued and conclusion*)

	Structural member		Space type	Operation on site			Inspection/maintenance			Transit			Flooded		
				Draught	S	S+D	Draught	S	S+D	Draught	S	S+D	Draught	S	S+D
					Load	Load		Load	Load		Load	Load		Load	Load
INTERNAL MEMBERS	Transverse bulkheads	Space forward of bulkhead	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}
		Space aft of bulkhead	Tanks designed for liquid filling	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Light load Deep load	P_{in}	P_{in}	Flooded	P_{in}	P_{in}
			Watertight boundaries/ void space				Light load Deep load	P_{in}	P_{in}				Flooded	P_{in}	P_{in}
			Dry spaces										Flooded	P_{in}	P_{in}

NOTES

1. When the unit's configuration cannot be described by Table 3.2.7, the applicable Design Load Sets to determine the scantling requirements of structural boundaries are to be selected so as to specify a full tank on one side with the adjacent tank or space empty. The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents, and are to maximise the pressure on the structural boundary. The applicable draught is to be taken in accordance with the Design Load Set and this Table. Design Load Sets covering the S and S+D design load combinations are to be selected.
2. Load cases for exposed decks are to consider any other distributed or concentrated loads, whereby simultaneously occurring green sea pressure may be ignored. Load cases for internal decks are to consider any other distributed or concentrated loads when green sea pressure is not applicable.
3. Ship motion parameters of GM and k_r are to be selected according to the loading condition.
4. Light load draught to be taken as the minimum for the load scenario under consideration (Operation, Inspection/maintenance, Transit). The minimum draught may vary between load scenarios.
5. Deep load draught to be taken as the maximum for the load scenario under consideration (Operation, Inspection/maintenance, Transit). The maximum draught may vary between load scenarios.
6. Draughts for flooded conditions to be taken as the deepest flooded draught in way of compartment under assessment.
7. Under the assumption that the ship unit is at sea, external sea pressure will always be present. Therefore, the design load set to assess the external shell envelope when the dominant load direction is from inside the hull outwards may be taken as P_{in}-P_{ex}.

Section 3
Forward of the forward cargo tank

3.1 Symbols

3.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
B = moulded breadth, in metres
D = moulded depth, in metres
T_{SC} = deep load draught, in metres
T_{LT} = minimum design light load draught, in metres
E = modulus of elasticity, in N/mm^2
σ_{yd} = specified minimum yield stress of the material, in N/mm^2
$\tau_{yd} = \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2
s = stiffener spacing, in mm
p = design pressure for the design load set being considered, in kN/m^2
g = acceleration due to gravity, 9,81 m/s^2
k = higher strength steel factor, defined in Ch 1,3.1.7.

3.2 General

3.2.1 **Application**.

3.2.1.1 The requirements of this Section apply to structure forward of the forward end of the foremost cargo tank. Where the forward end of the foremost cargo tank is aft of 0,1L of the unit's length, measured from the F.P., special consideration will be given to the applicability of these requirements and the requirements of Section 2.

3.2.2 **General scantling requirements.**

3.2.2.1 The deck plating thickness and supporting structure are to be suitably reinforced in way of deck machinery and topside units.

3.2.3 **Structural continuity.**

3.2.3.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the forward end. *See also* 1.6.

3.2.3.2 All shell frames and tank boundary stiffeners are to be continuous, or are to be bracketed at their ends.

3.2.4 **Minimum thickness.**

3.2.4.1 In addition to the required scantlings given in this Section, the plating and stiffeners are to comply with the minimum thickness requirements for the cargo region given in Tables 3.2.1 and 3.2.2, except as given in Table 3.3.1.

Table 3.3.1 Minimum net thickness of structure forward of the forward cargo tank

Scantling location	Net thickness (mm)
Pillar bulkheads	7,5
Breasthooks	6,5
Floors and bottom girders	5,5 + 0,02L_2
Web plating of primary support members	6,5 + 0,015L_2

3.3 Bottom structure

3.3.1 **Plate keel.**

3.3.1.1 A flat plate keel is to extend as far forward as practical and is to satisfy the scantling requirements given in 2.3.1.

3.3.2 **Bottom shell plating.**

3.3.2.1 The thickness of the bottom shell plating is to comply with the requirements in 3.11.2.1.

3.3.3 **Bottom longitudinals.**

3.3.3.1 Bottom longitudinals are to be carried as far forward as practicable. Beyond this, suitably stiffened frames are to be fitted.

3.3.3.2 The section modulus and thickness of the bottom longitudinals are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.3.4 **Bottom floors.**

3.3.4.1 Bottom floors are to be fitted at each web frame location. The minimum depth of the floor at the centreline is not to be less than the depth of the floors within the cargo tank region.

3.3.5 **Bottom girders.**

3.3.5.1 A supporting structure is to be provided at the centreline, either by extending the centreline girder to the stem or by providing a deep girder or centreline bulkhead.

3.3.5.2 Where a centreline girder is fitted, the minimum depth and thickness is not to be less than that fitted in the cargo tank region, and the upper edge is to be stiffened. Where a centreline wash bulkhead is fitted, the lowest strake is to have thickness not less than required for a centreline girder.

3.3.6 **Plate stems.**

3.3.6.1 Plate stems are to be supported by stringers and flats, and by intermediate breasthook diaphragms spaced not more than 1500 mm apart, measured along the stem. Where the stem radius is large, a centreline support structure is to be fitted.

3.3.6.2 Between the minimum design light draught, T_{LT}, at the stem and the deep load draught, T_{SC}, the plate stem net thickness, $t_{stem\text{-}net}$, is not to be less than:

$$t_{stem\text{-}net} = \frac{L_2 \sqrt{\frac{235}{\sigma_{yd}}}}{12}$$ mm, but need not be taken as greater than 21 mm

Above the deep load draught, the thickness of the stem plate may be tapered to the requirements for the shell plating at the upper deck.

Below the minimum design light load draught, the thickness of the stem plate may be tapered to the requirements for the plate keel.

3.3.7 **Floors and girders in spaces aft of the collision bulkhead.**

3.3.7.1 Floors and girders which are aft of the collision bulkhead and forward of the forward cargo tank are to comply with the requirements in 3.3.4 and 3.3.5 and are to comply with the shear area requirements in 3.11.3.3.

3.4 Side structure

3.4.1 **Side shell plating.**

3.4.1.1 The thickness of the side shell plating is to comply with the requirements in 3.11.2.1. Where applicable, the thickness of the side shell plating is to comply with the requirements in 2.3.4.2.

3.4.1.2 Where a forecastle is fitted, the side shell plating requirements are to be applied to the plating extending to the forecastle deck elevation.

3.4.2 **Side shell local support members.**

3.4.2.1 Longitudinal framing of the side shell is to be carried as far forward as practicable.

3.4.2.2 The section modulus and thickness of the hull envelope framing are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.4.2.3 End connections of longitudinals at transverse bulkheads are to provide adequate fixity, lateral support, and, where not continuous, are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be used.

3.4.3 **Side shell primary support structure.**

3.4.3.1 In general, the spacing of web frames, S, is to be taken as

$S = 2{,}6 + 0{,}005L_2$ m, but not to be taken greater than 3,5 m.

3.4.3.2 In general, for the transverse framing forward of the collision bulkhead, stringers are to be spaced approximately 3,5 m apart. Stringers are to have an effective span not greater than 10 m, and are to be adequately supported by web frame structures. Aft of the collision bulkhead, where transverse framing is adopted, the spacing of stringers may be increased.

3.4.3.3 Perforated flats are to be fitted to limit the effective span of web frames to not greater than 10 m.

3.4.3.4 The scantlings of web frames supporting longitudinal frames, and stringers and/or web frames supporting transverse frames in the forward region are to be determined from 3.11.3, with the following additional requirements:

(a) Where no cross ties are fitted:
- the required section modulus of the web frame is to be maintained for 60 per cent of the effective span for bending, measured from the lower end. The value of the bending moment used for calculation of the required section modulus of the remainder of the web frame may be appropriately reduced, but not greater than 20 per cent;
- the required shear area of the lower part of the web frame is to be maintained for 60 per cent of the shear span measured from the lower end.

(b) Where one cross tie is fitted:
- the effective spans for bending and shear of a web frame or stringer are to be taken, ignoring the presence of the cross tie. The shear forces and bending moments may be reduced to 50 per cent of the values that are calculated, ignoring the presence of the cross tie. For a web frame, the required section modulus and shear area of the lower part of the web frame are to be maintained up to the cross tie, and the required section modulus and shear area of the upper part of the web frame are to be maintained for the section above the cross tie;
- cross ties are to be designed using the design loads specified in Table 3.2.7.

(c) Configurations with multiple cross ties are to be specially considered, in accordance with 3.4.3.4(d).

(d) Where complex grillage structures are employed, the suitability of the scantlings of the primary support members is to be determined by more advanced calculation methods.

3.4.3.5 The web depth of primary support members is not to be less than 14 per cent of the bending span and is to be at least 2,5 times as deep as the slots for stiffeners if the slots are not closed.

3.5 Deck structure

3.5.1 **Deck plating.**

3.5.1.1 The thickness of the deck plating is to comply with the requirements in 3.11.2.1 with the applicable lateral pressure, green sea and deck loads.

3.5.2 **Deck stiffeners.**

3.5.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3, with the applicable lateral pressure, green sea and deck loads.

3.5.3 **Deck primary support structure.**

3.5.3.1 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

3.5.3.2 The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

3.5.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

3.5.4 **Pillars.**

3.5.4.1 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars. Where pillars support eccentric loads, they are to be strengthened for the additional bending moment imposed upon them.

3.5.4.2 Tubular and hollow square pillars are to be attached at their heads and heels by efficient brackets or doublers/insert plates, where applicable, to transmit the load effectively. Pillars are to be attached at their heads and heels by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be distributed by brackets or other equivalent means.

3.5.4.3 Pillars in tanks are to be of solid section. Where the hydrostatic pressure may result in tensile stresses in the pillar, the tensile stress in the pillar and its end connections is not to exceed 45 per cent of the specified minimum yield stress of the material.

3.5.4.4 The scantlings of pillars are to comply with the requirements in 3.11.5.

3.5.4.5 Where the loads from heavy equipment exceed the design load of 3.11.5, the pillar scantlings are to be determined based on the actual loading.

3.6 Tank bulkheads

3.6.1 **General.**

3.6.1.1 Tanks may be required to have divisions or deep wash plates in order to minimise the dynamic stress on the structure.

3.6.2 **Construction.**

3.6.2.1 In no case are the scantlings of tank boundary bulkheads to be less than the requirements for watertight bulkheads.

3.6.3 **Scantlings of tank boundary bulkheads.**

3.6.3.1 The thickness of tank boundary plating is to comply with the requirements in 3.11.2.1.

3.6.3.2 The section modulus and thickness of stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.6.3.3 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

3.6.3.4 Web plating of primary support members is to have a depth of not less than 14 per cent of the unsupported span in bending, and is not to be less than 2,5 times the depth of the slots if the slots are not closed.

3.6.3.5 Scantlings of corrugated bulkheads are to comply with the requirements in 3.11.4.

3.7 Watertight boundaries

3.7.1 **General.**

3.7.1.1 Watertight boundaries are to be fitted in accordance with Pt 4, Ch 3,5.

3.7.1.2 The number of openings in watertight bulkheads is to be kept to a minimum, compatible with the design and operation of the ship unit. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity.

3.7.2 **Scantlings of watertight boundaries.**

3.7.2.1 The thickness of boundary plating is to comply with the requirements in 3.11.2.1.

3.7.2.2 The section modulus and thickness of stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

3.7.2.3 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

3.7.2.4 Web plating of primary support members is to have a depth of not less than 10 per cent of the unsupported span in bending, and is not to be less than 2,5 times the depth of the slots if the slots are not closed.

3.7.2.5 Scantlings of corrugated bulkheads are to comply with the requirements in 3.11.4.

3.8 Superstructure

3.8.1 Forecastle structure.

3.8.1.1 Forecastle structures are to be supported by girders with deep beams and web frames, and, in general, arranged in complete transverse belts and supported by lines of pillars extending down into the structure below. Deep beams and girders are to be arranged, where practicable, to limit the spacing between deep beams, web frames, and/or girders to about 3,5 m. Pillars are to be provided as required by 3.5.4. Main structural intersections are to be carefully developed, with special attention given to pillar head and heel connections, and to the avoidance of stress concentrations.

3.9 Mooring systems

3.9.1 Supporting structure.

3.9.1.1 Where the structure is subjected to concentrated mooring loads from mooring arms or yokes, external turrets or mooring hawsers, etc., the scantlings and arrangements are to be specially considered. Finite element analysis of attachments to the hull is to be carried out to ensure satisfactory stress distribution of the mooring loads into the hull structure. The permissible local stress levels are to comply with the LR ShipRight Procedure for Ship Units and Pt 4, Ch 5, as applicable.

3.10 Miscellaneous structures

3.10.1 Pillar bulkheads.

3.10.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders are to be stiffened to provide supports no less effective than required for stanchions or pillars. The acting load and the required net cross-sectional area of the pillar section are to be determined using the requirements of 3.5.4. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$, where t_{net} is the net thickness of plating, in mm.

3.10.1.2 Pillar bulkheads are to comply with the following requirements:
(a) the distance between bulkhead stiffeners is not to exceed 1500 mm;
(b) where corrugated, the depth of the corrugation is not to be less than 100 mm.

3.11 Scantling requirements

3.11.1 General.

3.11.1.1 The design load sets are to be applied to the structural requirements for the local support and primary support members, as given in Table 3.2.7. The static and dynamic load components are to be combined in accordance with Table 3.6.1 and the procedure given in Chapter 2.

3.11.2 Plating and local support members.

3.11.2.1 For plating subjected to lateral pressure, the net plating thickness, t_{net}, is to comply with the requirements of Table 3.2.4, where C_a is taken as given in Table 3.3.2.

Table 3.3.2 Permissible bending stress coefficient for plating

Acceptance criteria set	Structural member	C_a
AC1	All plating	0,80
AC2	Hull envelope plating	0,95
	Internal boundary plating	1,00
AC3	All plating	1,0

3.11.2.2 For stiffeners subjected to lateral pressure, the net section modulus, Z_{net}, is to comply with the requirements of Table 3.2.5, where C_s is taken as given in Table 3.3.3.

Table 3.3.3 Permissible bending stress coefficient for stiffeners

Acceptance criteria set	Structural member	C_s
AC1	All stiffeners	0,75
AC2	All stiffeners	0,90
AC3	All stiffeners	1,0

3.11.2.3 For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements, $t_{w\text{-}net}$, is to comply with the requirements of Table 3.2.6, where C_t is taken as given in Table 3.3.4.

Table 3.3.4 Permissible shear stress coefficient for stiffeners

Acceptance criteria set	Structural member	C_t
AC1	All stiffeners	0,75
AC2	All stiffeners	0,90
AC3	All stiffeners	1,0

3.11.3 **Primary support members.**

3.11.3.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull. For side transverse frames, the requirements may be reduced due to the presence of cross ties, *see* 3.4.3.4.

3.11.3.2 For primary support members subjected to lateral pressure, the net section modulus, Z_{net50}, is to comply with 7.3.3.4 for all applicable design load sets in Table 3.2.7.

3.11.3.3 For primary support members subjected to lateral pressure, the effective net shear area, $A_{shr-net50}$, is to comply with 7.3.3.5 for all applicable design load sets in Table 3.2.7.

3.11.3.4 Primary support members are generally to be analysed with the specific methods described for the particular structure type. More advanced calculation methods may be necessary to ensure that nominal stress levels for all primary support members are less than the permissible stresses and stress coefficients given in 3.11.3.2 and 3.11.3.3 when subjected to the applicable design load sets.

3.11.4 **Corrugated bulkheads.**

3.11.4.1 Special consideration will be given to the approval of corrugated bulkheads, where fitted.

NOTE

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, *see* 2.6.6 and 2.6.7.

3.11.5 **Pillars.**

3.11.5.1 The maximum load on a pillar, W_{pill}, is to be taken as the greatest value calculated for all applicable design load sets, as given in Table 3.2.7, and is to be less than or equal to the permissible pillar load as given by the following equation, where $W_{pill-perm}$ is based on the net properties of the pillar:

$$W_{pill} \leq W_{pill-perm}$$

where

W_{pill} = applied axial load on pillar
= $P\, b_{a-sup}\, l_{a-sup} + W_{pill-upr}$ kN

$W_{pill-perm}$ = permissible load on a pillar
= $0{,}1 A_{pill-net50}\, \eta_{pill}\, \sigma_{crb}$ kN

b_{a-sup} = mean breadth of area supported, in metres

l_{a-sup} = mean length of area supported, in metres

$W_{pill-upr}$ = axial load from pillar or pillars above, in kN

$A_{pill-net50}$ = net cross-sectional area of the pillar, in cm^2

η_{pill} = utilisation factor for the design load set being considered:
= 0,5 for acceptance criteria set AC1
= 0,6 for acceptance criteria set AC2
= 0,6 for acceptance criteria set AC3

σ_{crb} = critical buckling stress in compression of pillar based on the net sectional properties, in N/mm^2.

Section 4 Machinery space

4.1 Symbols

4.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length in metres

L_2 = Rule length, L, but need not be taken greater than 300 m

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

s = stiffener spacing, in mm.

4.2 General

4.2.1 **Application.**

4.2.1.1 This Section prescribes scantling requirements for a machinery space or spaces located at any longitudinal frame location, such as a machinery space at the forward end. The requirements of this Section apply to all machinery spaces, regardless of location. For conventional self-propelled vessels, the requirements of Pt 3, Ch 7 of the Rules for Ships may also be used for guidance.

4.2.1.2 Where a machinery space is permitted to overlap either of the regions defined in Sections 3 and 5, the most onerous of the design requirements for the machinery space and the overlapping region are to take precedence.

4.2.1.3 Where a machinery space is located at a forward or aft region susceptible to local impact and slamming loads, the additional strengthening requirements prescribed in Section 6 are to be complied with in addition to the requirements in this Section.

4.2.2 **Arrangements.**

4.2.2.1 All machinery and related systems are to be supported to distribute the loads into the structure of the ship unit. The adjacent structure is to be suitably stiffened.

4.2.2.2 Primary support members are to be positioned giving consideration to the provision of through stiffeners and in-line pillar supports to achieve an efficient structural design.

4.2.2.3 The scantlings of the structure and the area of attachments are to consider the weight, power and proportions of the machinery, especially where the engines are positioned relatively high in proportion to the width of the bed plate.

4.2.2.4 The foundations for main machinery and, where fitted, propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity under all anticipated conditions of loading. It is recommended that plans of the above structure be submitted to the machinery manufacturer for review.

4.2.2.5 A cofferdam is to be provided to separate the cargo tanks from the machinery space. Pump-room, ballast tanks, or fuel oil tanks may be considered as cofferdams for this purpose.

4.2.2.6 When main auxiliary machinery is fitted above the weather deck, the machinery is to be protected by deck-houses, in accordance with Ch 1,10.1.1.

4.2.3 **Minimum thickness.**

4.2.3.1 In addition to the requirements for thickness, section modulus and shear area, as given in 4.3 to 4.9, the thickness of plating and stiffeners in the machinery space is to comply with applicable minimum thickness requirements for the cargo region given in Tables 3.2.1 and 3.2.2, except as applicable in Table 3.4.1.

Table 3.4.1 Minimum net thickness of structure in the machinery space

Scantling location		Net thickness (mm)
Plating	Lower decks and flats	$3,3 + 0,0067s$
	Inner bottom	$6,5 + 0,02L_2$
Floors and bottom longitudinal girders off centreline		$5,5 + 0,02L_2$
Web plating of primary support members		$5,5 + 0,015L_2$

4.3 Bottom structure

4.3.1 **General**

4.3.1.1 In general, a double bottom is to be fitted in the machinery space. The depth of the double bottom is to be at least the same as required in the cargo tank region. Where the depth of the double bottom in the machinery space differs from that in the adjacent spaces, continuity of the longitudinal material is to be maintained by sloping the inner bottom over a suitable longitudinal extent. Lesser double bottom height may be accepted in local areas, provided that the overall strength of the double bottom structure is not thereby impaired.

4.3.2 **Bottom shell plating.**

4.3.2.1 The keel plate breadth is to comply with the requirements in 2.3.1.1.

4.3.2.2 The thickness of the bottom shell plating (including keel plating) is to comply with the requirements in 4.9.1.1.

4.3.3 **Bottom shell stiffeners.**

4.3.3.1 The section modulus and thickness of bottom shell stiffeners are to comply with the requirements in 4.9.1.2 and 4.9.1.3.

4.3.4 **Girders and floors.**

4.3.4.1 The double bottom is to be arranged with a centre-line girder.

4.3.4.2 Full depth bottom girders are to be arranged in way of the main machinery to distribute its weight effectively and to ensure rigidity of the structure. The girders are to be carried as far forward and aft as practicable, and be suitably supported at their ends to provide distribution of loads from the machinery. The girders are to be tapered beyond their required extent.

4.3.4.3 Where the bottom is transversely framed, plate floors are to be fitted at every frame.

4.3.4.4 Where the bottom is longitudinally framed, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

4.3.4.5 Where heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

4.3.5 **Inner bottom plating.**

4.3.5.1 Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. Hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and the arrangements of hold-down bolts are also to consider the manufacturer’s recommendations.

4.3.6 **Sea chests**

4.3.6.1 Where the inner bottom or double bottom structure forms part of a sea chest, the thickness of the plating is not to be less than that required for the shell at the same location, taking into account the maximum unsupported width of the plating.

4.4 Side structure

4.4.1 **General.**

4.4.1.1 The scantlings of the side shell plating and longitudinals are to be properly tapered from the midship region towards the aft end.

4.4.1.2 A suitable scarphing arrangement of the longitudinal framing is to be arranged where the longitudinal framing terminates and is replaced by transverse framing.

4.4.1.3 Stiffeners and primary support members are to be supported at their ends.

4.4.2 **Side shell plating.**

4.4.2.1 The thickness of the side shell plating is to comply with the requirements in 4.9.1.1. Where applicable, the thickness of the side shell plating is to comply with the requirements in 2.3.4.2.

4.4.3 **Side shell local support members.**

4.4.3.1 The section modulus and thickness of side longitudinal and vertical stiffeners are to comply with the requirements in 4.9.1.2 and 4.9.1.3.

4.4.3.2 End connections of longitudinals at transverse bulkheads are to provide fixity, lateral support, and, when not continuous, are to be provided with soft-nosed brackets. Brackets lapped onto the longitudinals are not to be fitted.

4.4.4 **Side shell primary support members.**

4.4.4.1 Web frames are to be connected at the top and bottom to members of suitable stiffness, and supported by deck transverses.

4.4.4.2 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces.

4.4.4.3 The section modulus and shear area of primary support members are to comply with the requirements in 4.9.2.

4.4.4.4 The web depth is to be not less than 2,5 times the web depth of the adjacent frames if the slots are not closed.

4.4.4.5 Web plating of primary support members is to have a depth of not less than 14 per cent of the unsupported span in bending.

4.5 Deck structure

4.5.1 **General.**

4.5.1.1 All openings are to be framed. Attention is to be paid to structural continuity. Abrupt changes of shape, section or plate thickness are to be avoided.

4.5.1.2 The corners of the machinery space openings are to be of suitable shape and design to minimise stress concentrations.

4.5.1.3 In way of machinery openings, deck or flats are to have sufficient strength where they are intended as effective supports for side transverse frames or web frames.

4.5.1.4 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

4.5.1.5 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

4.5.1.6 Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

4.5.1.7 The structural scantlings are not to be less than the requirement for tank boundaries if the deck forms the boundary of a tank.

4.5.1.8 The structural scantlings are not to be less than the requirement for watertight bulkheads if the deck forms the boundary of a watertight space.

4.5.2 **Deck scantlings.**

4.5.2.1 The plate thickness of deck plating is to comply with the requirements in 4.9.1.1.

4.5.2.2 The section modulus and thickness of deck stiffeners are to comply with the requirements in 4.9.1.2 and 4.9.1.3.

4.5.2.3 The web depth of deck stiffeners is to be not less than 60 mm.

4.5.2.4 The section modulus and shear area of primary support members are to comply with the requirements in 4.9.2.

4.5.2.5 The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

4.5.2.6 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

4.5.3 **Pillars.**

4.5.3.1 Pillars are to comply with the requirements of 3.5.4.

4.5.3.2 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

4.6 Machinery foundations

4.6.1 **General.** *4.6.1.1* Main engines and thrust bearings are to be effectively secured to the hull structure by foundations of sufficient strength to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

4.6.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integral with the double bottom structure. Consideration is to be given to increase substantially the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case, and the thrust bearing.

4.6.1.3 For ship units with open floors in the machinery space, the foundations are generally to be arranged above the level of the top of the floors and securely bracketed.

4.6.2 **Foundations for internal combustion engines and thrust bearings.**

4.6.2.1 In determining the scantlings of foundations for internal combustion engines and thrust bearings, consideration is to be given to the general rigidity of the engine and to its design characteristics with regard to out of balance forces.

4.6.2.2 Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.
NOTE
In general, the gross thickness of foundation top plates is not to be less than 45 mm, where the maximum continuous output of the propulsion machinery is 3500 kW or greater.

4.6.3 **Auxiliary foundations.**

4.6.3.1 Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

4.7 Tank bulkheads

4.7.1 **General.**

4.7.1.1 Tanks are to comply with the requirements of 3.6, with scantlings determined using the factors from Table 3.4.2 and Table 3.4.3.

Table 3.4.2 Permissible bending stress coefficient for plating

The permissible bending stress coefficient, C_a, for the design load set being considered is to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{\sigma_{yd}} \quad \text{but not to be taken greater than } C_{a\text{-max}}$$

where
β_a, α_a, $C_{a\text{-max}}$

Acceptance criteria set	Structural member		β_a	α_a	$C_{a\text{-max}}$
AC1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely or vertically stiffened plating	0,9	1,0	0,8
	Other members		0,8	0	0,8
AC2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely or vertically stiffened plating	1,05	1,0	0,95
	Other members, including watertight boundary plating		1,0	0	1,0
AC3	All members		1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the load calculation point

$$= \frac{(z - z_{NA\text{-net50}})\, M_{v\text{-total}}}{I_{v\text{-net50}}} 10^{-3} \quad \text{N/mm}^2$$

$M_{v\text{-total}}$ = design vertical bending moment at the longitudinal position under consideration for the design load set being considered, in kNm. The still water bending moment, $M_{sw\text{-perm}}$, is to be taken with the same sign as the simultaneously acting wave bending moment, M_{wv}, *see* Table 2.6.1 in Chapter 2

$I_{v\text{-net50}}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4

z = vertical coordinate of the load calculation point under consideration, in metres

$z_{NA\text{-net50}}$ = distance from the baseline to the horizontal neutral axis, in metres

Table 3.4.3 Permissible bending stress coefficient for stiffeners

The permissible bending stress coefficient C_s is to be taken as:

Sign of hull girder bending stress, σ_{hg}	Side that pressure is acting on	Acceptance criteria
Tension (+ve)	Stiffener side	$C_s = \beta_s - \alpha_s \dfrac{\lvert\sigma_{hg}\rvert}{\sigma_{yd}}$ but not to be taken greater than $C_{s\text{-}max}$
Compression (–ve)	Plate side	
Tension (+ve)	Plate side	$C_s = C_{s\text{-}max}$
Compression (–ve)	Stiffener side	

where

β_s, α_s, $C_{s\text{-}max}$ = permissible bending stress factors and are to be taken as:

Acceptance criteria set	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC1	Longitudinally effective stiffeners	0,85	1,0	0,75
	Other stiffeners	0,75	0	0,75
AC2	Longitudinally effective stiffeners	1,0	1,0	0,9
	Other stiffeners	0,9	0	0,9
	Watertight boundary stiffeners	0,9	0	0,9
AC3	All members	1,0	0	1,0

σ_{hg} = hull girder bending stress for the design load set being considered and calculated at the reference point

$= \dfrac{(z - z_{NA\text{-}net50})\, M_{v\text{-}total}}{I_{v\text{-}net50}}\, 10^{-3}$ N/mm^2

$M_{v\text{-}total}$ = design vertical bending moment at longitudinal position under consideration for the design load set being considered, in kNm
$M_{v\text{-}total}$ is to be calculated in accordance with Table 2.6.1 in Chapter 2 using the sagging or hogging still water bending moment

Stiffener location	$M_{sw\text{-}perm}$	
	Pressure acting on plate side	Pressure acting on stiffener side
Above neutral axis	Sagging SWBM	Hogging SWBM
Below neutral axis	Hogging SWBM	Sagging SWBM

$I_{v\text{-}net50}$ = net vertical hull girder moment of inertia, at the longitudinal position being considered, in m^4
z = vertical coordinate of the reference point, in metres
$z_{NA\text{-}net50}$ = distance from the baseline to the horizontal neutral axis, in metres

4.8 Watertight boundaries

4.8.1 **General.**

4.8.1.1 Watertight boundaries are to comply with the requirements of 3.7, with scantlings determined using the factors from Table 3.4.2 and Table 3.4.3.

4.9 Scantling requirements

4.9.1 **Plating and local support members**.

4.9.1.1 For plating subjected to lateral pressure, the net plating thickness is to comply with the requirements of Table 3.2.4, where C_a is taken as given in Table 3.4.2.

4.9.1.2 For stiffeners subjected to lateral pressure, the net section modulus requirement is to comply with the requirements of Table 3.2.5, where C_s is taken as defined in Table 3.4.3.

4.9.1.3 For stiffeners subjected to lateral pressure, the net web thickness based on shear area requirements is to comply with the requirements of Table 3.2.6, where C_t is taken as given in Table 3.3.4 in the previous Section.

4.9.2 **Primary support members.**

4.9.2.1 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include allowance for the curvature of the hull.

4.9.2.2 For primary support members subjected to lateral pressure, the net section modulus requirement is to comply with the requirements in 3.11.3.2.

4.9.2.3 For primary support members subjected to lateral pressure, the net cross-sectional area of the web is to comply with the requirements in 3.11.3.3.

4.9.2.4 Primary support members are generally to be analysed with the specific methods as described for the particular structure type. More advanced calculation methods may be required to ensure that nominal stress level, for all primary support members are less than permissible stresses and stress coefficients given in 3.11.3.2 and 3.11.3.3, when subjected to the applicable design load sets.

4.9.3 **Corrugated bulkheads.**

4.9.3.1 Special consideration will be given to the approval of corrugated bulkheads, where fitted.

NOTE

Scantling requirements of corrugated bulkheads in the cargo tank region may be used as a basis, *see* 2.6.6 and 2.6.7.

4.9.4 **Pillars.**

4.9.4.1 The maximum load on a pillar is to be less than the permissible pillar load as given by the requirements in 3.11.5.

■ *Section 5* Aft end

5.1 Symbols

5.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
s = stiffener spacing, in mm.

5.2 General

5.2.1 **Application.**

5.2.1.1 The requirements of this Section apply to structure located between the aft peak bulkhead and the aft end of the ship unit.

5.2.1.2 The requirements of this Section do not apply to the following:

(a) rudder horns;
(b) structures which are not integral with the hull, such as rudders, steering nozzles and propellers;
(c) other appendages permanently attached to the hull.

Where such items are fitted, the relevant requirements of the Rules for Ships are to be complied with.

5.2.1.3 The deck plating thickness and supporting structure are to be suitably reinforced for the steering gear, mooring windlasses, and other deck machinery.

5.2.2 **Structural continuity.**

5.2.2.1 Scantlings of the shell envelope, upper deck and inner bottom are to be tapered towards the aft end. *See also* 1.6.

5.2.2.2 Longitudinal framing of the strength deck is to be carried aft to the stern.

5.2.2.3 All shell frames and tank boundary stiffeners are, in general, to be continuous or bracketed at their ends.

5.2.3 **Minimum thickness.**

5.2.3.1 In addition to the scantling requirements as given in 5.3 to 5.8, the plating and stiffeners are to comply with the minimum thickness requirements for the cargo region, except as given in Table 3.5.1.

Table 3.5.1 Minimum net thickness of structure aft of the aft peak bulkhead

Scantling location	Net thickness (mm)
Pillar bulkhead plating	7,5
Bottom girders and aft peak floors	$5,5 + 0,02L_2$
Web plating of primary support members	$6,5 + 0,015L_2$

5.3 Bottom structure

5.3.1 **General.**

5.3.1.1 Floors are to be fitted at each frame space in the aft peak and carried to a height at least above the stern tube, where fitted. Where floors do not extend to flats or decks, they are to be stiffened by flanges at their upper end.

5.3.1.2 The centreline bottom girder is to extend as far aft as is practicable and be suitably scarphed into the stern frame or transom.

5.3.1.3 For self-propelled units with conventional propulsion and steering arrangements, the relevant Sections of the Rules for Ships are to be complied with.

5.4 Shell structure

5.4.1 **Shell plating.**

5.4.1.1 The net thickness of the side shell and transom plating, t_{net}, is to comply with the requirements in 3.11.2.1.

5.4.1.2 The net plating thickness of shell, t_{net}, attached to the stern frame is to comply with the requirements in 3.11.2.1 and is not to be less than:

$$t_{net} = 0{,}094\,(L_2 - 43) + 0{,}009s \quad \text{mm.}$$

5.4.1.3 In way of the boss and heel plate, the shell net plating thickness, t_{net}, is not to be less than:

$$t_{net} = 0{,}105\,(L_2 - 47) + 0{,}011s \quad \text{mm.}$$

5.4.1.4 Within the extents specified in 2.3.4.3, the thickness of the side shell plating is to comply with the requirements in 2.3.4.2.

5.4.2 **Shell local support members.**

5.4.2.1 The section modulus and thickness of the hull envelope framing are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

5.4.3 **Shell primary support members.**

5.4.3.1 The requirements of 5.4.3 apply to single side skin construction supported by a system of vertical webs and/or horizontal stringers or flats.

5.4.3.2 Where a longitudinal framing system is adopted, longitudinals are to be supported by vertical primary support members extending from the floors to the upper deck. Deck transverses are to be fitted in line with the web frames.

5.4.3.3 Where a transverse framing system is adopted, frames are to be supported by horizontal primary support members spanning between the vertical primary support members.

5.4.3.4 The scantlings of web frames supporting longitudinal framing, stringers and transverse framing are to be determined from 3.11.3.

5.4.3.5 The web depth of primary support members is not to be less than 14 per cent of the bending span and is to be at least 2,5 times as deep as the slots for stiffeners if the slots are not closed.

5.5 Deck structure

5.5.1 **Deck plating.**

5.5.1.1 The thickness of the deck plating is to comply with the requirements in 3.11.2.1.

5.5.2 **Deck stiffeners.**

5.5.2.1 The section modulus and thickness of deck stiffeners are to comply with the requirements in 3.11.2.2 and 3.11.2.3.

5.5.3 **Deck primary support members.**

5.5.3.1 The section modulus and shear area of primary support members are to comply with the requirements in 3.11.3.

5.5.3.2 The web depth of primary support members is not to be less than 10 per cent and 7 per cent of the unsupported span in bending in tanks and in dry spaces, respectively, and is not to be less than 2,5 times the depth of the slots if the slots are not closed. In the case of a grillage structure, the unsupported span is the distance between connections to other primary support members.

5.5.3.3 In way of concentrated loads from heavy equipment, the scantlings of the deck structure are to be determined based on the actual loading.

5.5.4 **Pillars.**

5.5.4.1 Pillars are to comply with the requirements of 3.5.4.

5.6 Tank bulkheads

5.6.1 **General.**

5.6.1.1 Tanks are to comply with the requirements of 3.6.

5.7 Watertight boundaries

5.7.1 **General.**

5.7.1.1 Watertight boundaries are to comply with the requirements of 3.7.

5.7.2 **Aft peak bulkhead.**

5.7.2.1 The scantlings of structural components of the aft peak bulkhead are to comply with the requirements in 3.6 and 3.7.2, as applicable.

5.8 Miscellaneous structures

5.8.1 **Pillar bulkheads.**

5.8.1.1 Bulkheads that support girders, or pillars and longitudinal bulkheads which are fitted in lieu of girders, are to be stiffened to provide supports no less effective than those required for stanchions or pillars. The acting load and the required net cross-sectional area of the pillar section are to be determined using the requirements of 5.5.4. The net moment of inertia of the stiffener is to be calculated with a width of $40t_{net}$ of the plating, where t_{net} is net plating thickness, in mm.

5.8.1.2 Pillar bulkheads are to meet the following requirements:

(a) the distance between bulkhead stiffeners is not to exceed 1500 mm;
(b) where corrugated, the depth of the corrugation is not to be less than 100 mm.

5.8.2 **Rudder trunk.**

5.8.2.1 Where a rudder trunk is fitted, the scantlings are to be in accordance with the shell plating and framing in 5.4.1 and 5.4.2. Where the rudder trunk is open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment.

5.8.3 **Stern thruster tunnels.**

5.8.3.1 The net thickness of the tunnel plating, $t_{tun\text{-}net}$, is not to be less than required for shell plating in the vicinity of the thruster. In addition $t_{tun\text{-}net}$ is not to be taken less than:

$t_{tun-net} = 0{,}008d_{tun} + 1{,}8$ m

where

d_{tun} = inside diameter of tunnel, in mm, but not to be taken less than 970 mm.

5.8.3.2 Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

Section 6
Evaluation of structure for sloshing and impact loads

6.1 Symbols

6.1.1 The symbols used in this Chapter are defined as follows:

L = Rule length, in metres
L_2 = Rule length, L, but need not be taken greater than 300 m
B = moulded breadth, in metres
D = moulded depth, in metres
C_b = block coefficient
σ_{yd} = specified minimum yield stress of the material, in N/mm^2
$\tau_{yd} = \dfrac{\sigma_{yd}}{\sqrt{3}}$ N/mm^2
s = stiffener spacing, in mm
P = design pressure for the design load set being considered, in kN/m^2.

6.2 General

6.2.1 **Application.**

6.2.1.1 The requirements of this Section cover the additional strengthening requirements for localised sloshing loads that may occur in tanks carrying liquid and local impact loads in the forward and aft structure. The impact loads to be applied in 6.4 are described in Ch 2,4.

6.3 Sloshing in tanks

6.3.1 **Scope and limitations.**

6.3.1.1 The requirements of the LR ShipRight Procedure for Ship Units specify the methodology in assessing the scantling requirements for boundary and internal structure of tanks subject to sloshing loads, due to the free movement of liquid in tanks.

6.3.1.2 The structure of cargo tanks, slop tanks, ballast tanks and large deep tanks, e.g., fuel oil bunkering tanks and main fresh water tanks, is to be assessed for sloshing. Small tanks do not need to be assessed for sloshing pressures.

6.3.1.3 All cargo and ballast tanks are to have scantlings suitable for unrestricted filling heights.

6.3.1.4 The following structural members are to be assessed:

(a) plates and stiffeners forming boundaries of tanks;
(b) plates and stiffeners on wash bulkheads;
(c) web plates and web stiffeners of primary support members located in tanks;
(d) tripping brackets supporting primary support members in tanks.

6.4 Bottom slamming

6.4.1 **Application.**

6.4.1.1 Where the minimum draughts forward, $T_{FP\text{-}mt}$ or $T_{FP\text{-}full}$, as specified in Chapter 2, is less than 0,045*L*, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

6.4.1.2 For self-propelling units with conventional single screw, ship-type aft sections, additional strengthening against aft slamming will not normally be required. For units with full deep aft sections, strengthening to resist bottom slamming should be applied over 0,3*L* aft, using the requirements of 6.4.3 and 6.4.4 and the applicable draughts aft. Units with raised or unusual sections aft that may be susceptible to slamming will be specially considered, using the requirements of Pt 4, Ch 2,4.3 and 5.2 of the Rules for Ships.

6.4.1.3 The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, *see* 1.2.

6.4.1.4 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The cross-sectional shear areas of primary support members are to be applied as required by 6.4.7.3 and 6.4.7.4.

6.4.1.5 For harsh service, special consideration should be given to strengthening of bottom forward in relation to the actual forces determined from model tests and/or direct calculations.

6.4.2 **Extent of strengthening.**

6.4.2.1 The strengthening is to extend forward of 0,3*L* from the F.P. over the flat of bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the base-line, *see* Fig. 3.6.1.

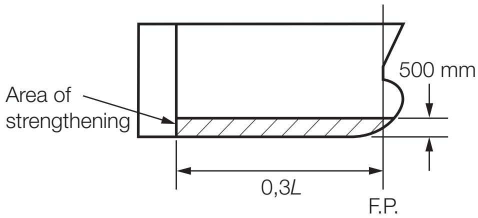


Fig. 3.6.1
Extent of strengthening against bottom slamming

6.4.2.2 Outside the region strengthened to resist bottom slamming, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

6.4.3 **Design to resist bottom slamming loads.**

6.4.3.1 The design of end connections of stiffeners in the bottom slamming region is to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl\text{-}net}}{f_{bdg}} \text{ cm}^3$$

where

$Z_{pl\text{-}net}$ = net plastic section modulus, in cm^3, as required by 6.4.5.1

f_{bdg} = bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 0 for both ends with low end fixity (simply supported)

= 1 for one end equivalent to built in and one end simply supported.

6.4.3.2 Scantlings and arrangements at primary support members, including bulkheads, are to comply with 6.4.7.

6.4.4 **Hull envelope plating**.

6.4.4.1 The net thickness of the hull envelope plating, t_{net}, is not to be less than:

$$t_{net} = \frac{0{,}0158 \alpha_p s}{C_d} \sqrt{\frac{P_{slm}}{C_a \sigma_{yd}}} \text{ mm}$$

where

α_p = correction factor for the panel aspect ratio

$= 1{,}2 - \frac{s}{2100 l_p}$

but not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing between primary support members or panel breakers, in metres

P_{slm} = bottom slamming pressure as given in Ch 2,4.2.2.1 and calculated at the load calculation point, in kN/m^2

C_d = plate capacity correction coefficient

= 1,3

C_a = permissible bending stress coefficient

= 1,0 for acceptance criteria set AC3.

6.4.5 **Hull envelope stiffeners**.

6.4.5.1 The net plastic section modulus, $Z_{pl\text{-}net}$, of each individual stiffener, is not to be less than:

$$Z_{pl\text{-}net} = \frac{P_{slm}\, s\, l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3$$

where

l_{bdg} = effective bending span, in metres

f_{bdg} = bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 2,0 for continuous stiffeners or where stiffeners are bracketed at both ends, *see* 6.4.3.1 for alternative arrangements

C_s = permissible bending stress coefficient
= 0,9 for acceptance criteria set AC3.

6.4.5.2 The net web thickness, $t_{w\text{-}net}$, of each longitudinal is not to be less than:

$$t_{w\text{-}net} = \frac{P_{slm}\, s\, l_{shr}}{2d_{shr}\, C_t\, \tau_{yd}} \text{ mm}$$

where

l_{shr} = effective shear span, in metres

d_{shr} = effective web depth of stiffener, in mm

C_t = permissible shear stress coefficient
= 1,0 for acceptance criteria set AC3.

6.4.6 **Definition of idealised bottom slamming load area for primary support members**.

6.4.6.1 The scantlings of items in 6.4.7 are based on the application of the slamming pressure defined in Chapter 2 to an idealised area of hull envelope plating, the slamming load area, A_{slm}, given by:

$$A_{slm} = \frac{1{,}1LBC_b}{1000} \text{ m}^2.$$

6.4.7 **Primary support members**.

6.4.7.1 The size and number of openings in web plating of the floors and girders are to be minimised, considering the required shear area as given in 6.4.7.2.

6.4.7.2 The net shear area, $A_{shr\text{-}net50}$, of each primary support member web at any position along its span is not to be less than:

$$A_{shr\text{-}net50} = 10\, \frac{Q_{slm}}{C_t\, \tau_{yd}} \text{ cm}^2$$

where

Q_{slm} = the greatest shear force due to slamming for the position being considered, in kN, based on the application of a patch load, F_{slm}, to the most onerous location, as determined in accordance with 6.4.7.3

C_t = permissible shear stress coefficient
= 0,9 for acceptance criteria set AC3.

6.4.7.3 For simple arrangements of primary support members, where the grillage effect may be ignored, the shear force, Q_{slm}, is given by:

$$Q_{slm} = f_{pt}\, f_{dist}\, F_{slm} \quad \text{kN}$$

where

f_{pt} = correction factor for the proportion of patch load acting on a single primary support member
= $0{,}5\,(f_{slm}^3 - 2f_{slm}^2 + 2)$

f_{slm} = patch load modification factor
= $0{,}5\, \dfrac{b_{slm}}{S}$, but not to be greater than 1,0

f_{dist} = factor for the greatest shear force distribution along the span, *see* Fig. 3.6.2

F_{slm} = $P_{slm}\, l_{slm}\, b_{slm}$

l_{slm} = extent of slamming load area along the span
= $\sqrt{A_{slm}}$ m, but not to be greater than l_{shr}

l_{shr} = effective shear span, in metres

b_{slm} = breadth of impact area supported by primary support member
= $\sqrt{A_{slm}}$ m, but not to be greater than S

A_{slm} = as defined in 6.4.6.1

S = primary support member spacing, in metres.

6.4.7.4 For complex arrangements of primary support members, the greatest shear force, Q_{slm}, at any location along the span of each primary support member is to be derived by direct calculation in accordance with Table 3.6.1.

6.4.7.5 The net web thickness, $t_{w\text{-}net}$, of primary support members adjacent to the shell is not to be less than:

$$t_{w\text{-}net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \text{ mm}$$

where

s_w = plate breadth, in mm, taken as the spacing between the web stiffening.

6.4.8 **Connection of longitudinals to primary support members**.

6.4.8.1 Longitudinals are, in general, to be continuous. Where this is not practicable, end brackets are to be provided.

6.4.8.2 The scantlings in way of the end connections of each longitudinal are to comply with the requirements of 1.10.

6.5 Bow impact

6.5.1 **Application**.

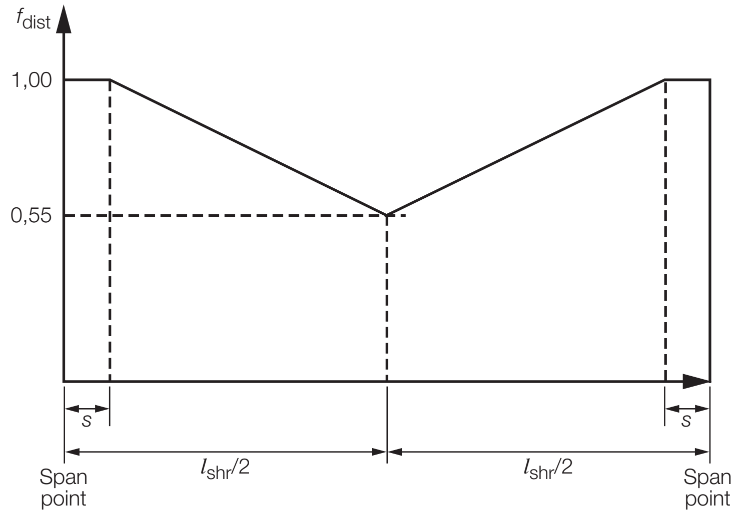
6.5.1.1 The side structure in the area forward of 0,1L from the FP is to be strengthened against bow impact pressures.

6.5.1.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus of the primary support member is to apply along the bending span clear of end brackets and cross-sectional areas of the primary support member are to be applied at the ends/supports and may be gradually reduced along the span and clear of the ends/supports following the distribution of f_{dist} indicated in Fig. 3.6.2.

6.5.2 **Extent of strengthening**.

6.5.2.1 The strengthening is to extend forward of 0,1L from the FP and vertically above the minimum design light load draught, T_{LT}, *see* Fig. 3.6.3.

6.5.2.2 Outside the strengthening region, as given in 6.5.2.1, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.



s = stiffener plating
l_{shr} = effective shear span, in metres

Fig. 3.6.2 Distribution of f_{dist} along the span of simple primary support members

Table 3.6.1 Direct calculation methods for derivation of Q_{slm}

Type of analysis	Beam theory	Double bottom grillage
Model extent	Overall span of member between effective bending supports	Longitudinal extent to be one cargo tank length Transverse extent to be between inner hopper knuckle and centreline
Assumed end fixity of floors	Fixed at ends	Floors and girders to be fixed at boundaries of the model
NOTE The envelope of greatest shear force along each primary support member is to be derived by applying the load patch to a number of locations along the span, *see* 6.4.7.2.		

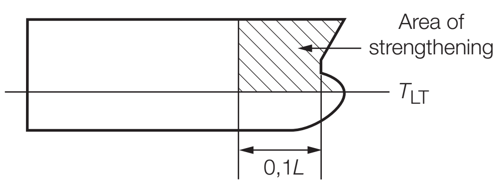


Fig. 3.6.3
Extent of strengthening against bow impact

6.5.3 **Design to resist bow impact loads**.

6.5.3.1 In the bow impact region, longitudinal framing is to be carried as far forward as practicable.

6.5.3.2 The design of end connections of stiffeners in the bow impact region are to ensure end fixity, either by making the stiffeners continuous through supports or by providing end brackets. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{pl\text{-}alt\text{-}net}$, for alternative end fixity arrangements is not to be less than:

$$Z_{pl\text{-}alt\text{-}net} = \frac{16 Z_{pl\text{-}net}}{f_{bdg}} \text{ cm}^3$$

where

$Z_{pl\text{-}net}$ = effective net plastic section modulus, required by 6.5.5, in cm^3

f_{bdg} = bending moment factor

$= 8\left(1 + \frac{n_s}{2}\right)$

n_s = 0 for both ends with low end fixity (simply supported)

= 1,0 for one end equivalent to built-in and one end simply supported.

6.5.3.3 Scantlings and arrangements at primary support members, including decks and bulkheads, are to comply with 6.5.7. In areas of greatest bow impact load, the adoption of web stiffeners arranged perpendicular to the hull envelope plating and the provision of double sided lug connections are, in general, to be applied.

6.5.3.4 The main stiffening direction of decks and bulkheads supporting shell framing is to be arranged parallel to the span direction of the supported shell frames, to protect against buckling.

6.5.4 **Side shell plating**.

6.5.4.1 The net thickness of the side shell plating, t_{net}, is not to be less than:

$$t_{net} = 0{,}0158\alpha_p\, s \sqrt{\frac{P_{im}}{C_a\, \sigma_{yd}}} \text{ mm}$$

where

α_p = correction factor for the panel aspect ratio

$= 1{,}2 - \dfrac{s}{2100 l_p}$

but is not to be taken as greater than 1,0

l_p = length of plate panel, to be taken as the spacing between the primary support members, or panel breakers, in metres

P_{im} = bow impact pressure as given in Ch 2,4.3.2.1 and calculated at the load calculation point, in kN/m^2

C_a = permissible bending stress coefficient

= 1,0 for acceptance criteria set AC3.

6.5.5 **Side shell stiffeners**.

6.5.5.1 The effective net plastic section modulus, $Z_{pl\text{-}net}$, of each stiffener, in association with the effective plating to which it is attached, is not to be less than:

$$Z_{pl\text{-}net} = \frac{P_{im}\, s\, l_{bdg}^2}{f_{bdg}\, C_s\, \sigma_{yd}} \text{ cm}^3$$

where

l_{bdg} = effective bending span, in metres

f_{bdg} = bending moment factor

$= 8\left(1 + \dfrac{n_s}{2}\right)$

n_s = 2,0 for continuous stiffeners or where stiffeners are bracketed at both ends, *see* 6.4.3.1 for alternative arrangements

C_s = permissible bending stress coefficient

= 0,9 for acceptance criteria set AC3.

6.5.5.2 The net web thickness, $t_{w\text{-}net}$, of each stiffener is not to be less than:

$$t_{w\text{-}net} = \frac{P_{im}\, s\, l_{shr}}{2 d_{shr}\, C_t\, \tau_{yd}} \text{ mm}$$

where

l_{shr} = effective shear span, in metres

d_{shr} = effective web depth of stiffener, in mm

C_t = permissible shear stress coefficient

= 1,0 for acceptance criteria set AC3.

6.5.5.3 The minimum net thickness of breasthooks/diaphragm plates, $t_{w\text{-}net}$, is not to be less than:

$$t_{w\text{-}net} = \frac{s}{70}\sqrt{\frac{\sigma_{yd}}{235}} \text{ mm}$$

where

s = spacing of stiffeners on the web, in mm. Where no stiffeners are fitted, s is to be taken as the depth of the web.

6.5.6 **Definition of idealised bow impact load area for primary support members**.

6.5.6.1 The scantlings of items in 6.5.7 are based on the application of the bow impact pressure to an idealised area of hull envelope plating, where the bow impact load area, A_{slm}, is given by:

$$A_{slm} = \frac{1{,}1 LBC_b}{1000} \text{ m}^2.$$

6.5.7 **Primary support members**.

6.5.7.1 Primary support members in the bow impact region are to be configured to ensure effective continuity of strength and the avoidance of hard spots.

6.5.7.2 To limit the deflections under extreme bow impact loads and ensure boundary constraint for plate panels, the spacing, S, measured along the shell girth of web frames supporting longitudinal framing or stringers supporting transverse framing is not to be greater than:

$$S = 3 + 0{,}008 L_2 \text{ m.}$$

6.5.7.3 End brackets of primary support members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.

6.5.7.4 Tripping brackets are to be fitted where the primary support member flange is knuckled or curved. The torsional buckling mode of primary support members is to be controlled by flange supports or tripping brackets. The unsupported length of the flange of the primary support member, i.e., the distance between tripping brackets, s_{bkt}, is not to be greater than:

$$s_{bkt} = b_f\, C \sqrt{\frac{235}{\sigma_{yd}}\, \frac{A_{f\text{-}net50}}{\left(A_{f\text{-}net50} + \dfrac{A_{w\text{-}net50}}{3}\right)}} \text{ m,}$$

but need not be less than $s_{bkt\text{-}min}$

where

b_f = breadth of flange, in mm

C = slenderness coefficient:

= 0,022 for symmetrical flanges

= 0,033 for one-sided flanges

$A_{f\text{-}net50}$ = net cross-sectional area of flange, in cm^2

$A_{w\text{-}net50}$ = net cross-sectional area of the web plate, in cm^2

$s_{bkt\text{-}min}$ = 4,0 m.

6.5.7.5 The net section modulus of each primary support member, Z_{net50}, is not to be less than:

$$Z_{net50} = 1000 \frac{f_{bdg\text{-}pt} P_{im} b_{slm} f_{slm} l_{bdg}^2}{f_{bdg} C_s \sigma_{yd}} \text{ cm}^3$$

where

$f_{bdg\text{-}pt}$ = correction factor for the bending moment at the ends and considering the patch load
= $3f_{slm}^3 - 8f_{slm}^2 + 6f_{slm}$

f_{slm} = patch load modification factor
= $\dfrac{l_{slm}}{l_{slm}}$

l_{slm} = extent of bow impact load area along the span
= $\sqrt{A_{slm}}$ m, but not to be taken as greater than l_{bdg}

A_{slm} = bow impact load area, in m^2, as defined in 6.4.6.1

l_{bdg} = effective bending span, in metres

b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not to be taken as greater than l_{slm}, in metres

f_{bdg} = bending moment factor
= 12 for primary support members with end fixed continuous face-plates, stiffeners or where stiffeners are bracketed at both ends

C_s = permissible bending stress coefficient
= 0,8 for acceptance criteria set AC3.

6.5.7.6 The net shear area of the web, $A_{shr\text{-}net50}$, of each primary support member at the support/toe of end brackets is not to be less than:

$$A_{shr\text{-}net50} = \frac{5f_{pt} P_{im} b_{slm} l_{shr}}{C_t \tau_{yd}} \text{ cm}^2$$

where

f_{pt} = patch load modification factor
= $\dfrac{l_{slm}}{l_{shr}}$

l_{slm} = extent of bow impact load area along the span
= $\sqrt{A_{slm}}$ m,
but not to be taken as greater than l_{shr}

l_{shr} = effective shear span, in metres

b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not greater than l_{slm}, in metres

C_t = permissible shear stress coefficient
= 0,75 for acceptance criteria set AC3.

6.5.7.7 The net web thickness of each primary support member, $t_{w\text{-}net}$, including decks/bulkheads in way of the side shell, is not to be less than:

$$t_{w\text{-}net} = \frac{P_{im} b_{slm}}{\sin \varphi_w \sigma_{crb}} \text{ mm}$$

where

b_{slm} = breadth of impact load area supported by the primary support member, to be taken as the spacing between primary support members, but not greater than l_{slm}, in metres

φ_w = angle, in degrees, between the primary support member web and the shell plate

σ_{crb} = critical buckling stress in compression of the web of the primary support member or deck/bulkhead panel in way of the applied load, in N/mm^2.

6.5.8 **Connection of stiffeners to primary support members**.

6.5.8.1 Stiffeners are, in general, to be continuous. Where this is not practicable, end brackets are to be provided.

6.5.8.2 The scantlings of the end connection of each stiffener are to comply with the requirements of 1.10.

Section 7
Application of scantling requirements to other structure

7.1 Symbols

7.1.1 The symbols used in this Chapter are defined as follows:

σ_{yd} = specified minimum yield stress of the material, in N/mm^2

$$\tau_{yd} = \frac{\sigma_{yd}}{\sqrt{3}} \text{ N/mm}^2$$

s = stiffener spacing, in mm

S = primary support member spacing, in metres

F = point load for the design load set being considered, in kN

P = design pressure for the design load set being considered, in kN/m^2.

7.2 General

7.2.1 **Application**.

7.2.1.1 The requirements of this Section apply to plating, local and primary support members where the basic structural configurations or strength models assumed in Sections 2 to 5 are not appropriate. These are general-purpose strength requirements to cover various load assumptions and end support conditions.

7.2.1.2 The requirements for local and primary support members are to be specially considered when the member is:

(a) part of a grillage structure;

(b) subject to large relative deflection between end supports;

(c) where the load model or end support condition is not given in Table 3.7.2.

7.2.1.3 The application of alternative or more advanced calculation methods will be specially considered.

7.3 Scantling requirements

7.3.1 **General**.

7.3.1.1 The design load sets to be applied to the structural requirements for the local and primary support members are given in Table 3.2.7, as applicable for the particular structure under consideration. The static and dynamic load components are to be combined in accordance with Table 2.6.1 and the requirements given in Chapter 2.

7.3.2 **Plating and local support members**.

7.3.2.1 For plating subjected to lateral pressure, the net thickness, t_{net}, is to be taken as the greatest value for all applicable design load sets, and given by:

$$t_{net} = 0{,}0158\alpha_p\, s \sqrt{\frac{|P|}{C_a\, \sigma_{yd}}} \text{ mm}$$

where

α_p = correction factor for the panel aspect ratio

$= 1{,}2 - \dfrac{s}{2100 l_p}$

l_p = length of plate panel, to be taken as the spacing of primary support members, S, unless carlings are fitted, in metres

C_a = permissible bending stress coefficient for the design load set being considered, as given in Tables 3.2.4, 3.3.2 or 3.4.2, as applicable for the individual member being considered.

7.3.2.2 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net section modulus requirement, Z_{net}, is to be taken as the greatest value for all applicable design load sets, and given by:

$$Z_{net} = \frac{|P|\, s\, l_{bdg}^2}{f_{bdg}\, C_s\, \sigma_{yd}} \text{ cm}^3\text{, for lateral pressure loads}$$

$$Z_{net} = \frac{1000\, |F|\, l_{bdg}}{f_{bdg}\, C_s\, \sigma_{yd}} \text{ cm}^3\text{, for point loads}$$

$$Z_{net} = \frac{\left| \sum \dfrac{P_i\, s\, l_{bdg}^2}{f_{bdg\text{-}i}} + \sum \dfrac{1000 F_j\, l_{bdg}}{f_{bdg\text{-}j}} \right|}{C_s\, \sigma_{yd}} \text{ cm}^3,$$

for a combination of loads

where

l_{bdg} = effective bending span, in metres

f_{bdg} = bending moment factor

for continuous stiffeners and where end connections are fitted consistent with idealisation of the stiffener as having fixed ends:

= 12 for horizontal stiffeners

= 10 for vertical stiffeners

for other configurations the bending moment factor may be taken as in Table 3.7.2

C_s = permissible bending stress coefficient for the design load set being considered as given in Tables 3.2.5, 3.3.3 or 3.4.3, as applicable for the individual member being considered

i = indices for load component i

j = indices for load component j.

7.3.2.3 For stiffeners subjected to lateral pressure, point loads, or some combination thereof, the net web thickness, $t_{w\text{-}net}$, based on shear area requirements is to be taken as the greatest value for all applicable design load sets, and given by:

$$t_{w\text{-}net} = \frac{f_{shr}\,|P|\,s\,l_{shr}}{d_{shr}\,C_t\,\tau_{yd}} \text{ mm, for lateral pressure loads}$$

$$t_{w\text{-}net} = \frac{1000 f_{shr}\,|F|}{d_{shr}\,C_t\,\tau_{yd}} \text{ mm, for point loads}$$

$$t_{w\text{-}net} = \frac{\left|\sum f_{shr\text{-}i}\,P_i\,s\,l_{shr} + \sum 1000 f_{shr\text{-}j}\,F_j\right|}{d_{shr}\,C_t\,\tau_{yd}} \text{ mm,}$$

for a combination of loads

where

f_{shr} = shear force factor
for continuous stiffeners with end connections consistent with the idealisation of the stiffener as having fixed ends:
= 0,5 for horizontal stiffeners
= 0,7 for vertical stiffeners
for other configurations the shear force factor may be taken as in Table 3.7.2
l_{shr} = effective shear span, in metres
d_{shr} = effective shear depth, in mm
C_t = permissible shear stress coefficient for design load set, as given in Tables 3.2.6 or 3.3.4, for the individual member being considered
i = indices for load component i
j = indices for load component j.

7.3.3 **Primary support members**.

7.3.3.1 The requirements in 7.3.3 are applicable where the primary support member is idealised as a simple beam. More advanced calculation methods may be required to ensure that nominal stress levels for all primary support members are less than the permissible stresses and stress coefficients given in 7.3.3.4 and 7.3.3.5, when subjected to the applicable design load sets. *See also* 7.1.1.4.

7.3.3.2 The section modulus and web thickness of the local support members apply to the areas clear of the end brackets. The section modulus and cross-sectional shear areas of the primary support member are to be applied as required in the notes of Table 3.7.2.

7.3.3.3 For primary support members intersecting with or in way of curved hull sections, the effectiveness of end brackets is to include an allowance for the curvature of the hull.

7.3.3.4 For primary support members, the net section modulus requirement, Z_{net50}, is to be taken as the greatest value for all applicable design load sets, and given by:

$$Z_{net50} = \frac{1000\,|P|\,S\,l_{bdg}^2}{f_{bdg}\,C_{s\text{-}pr}\,\sigma_{yd}} \text{ cm}^3,$$

for lateral pressure loads

$$Z_{net50} = \frac{1000\,|F|\,l_{bdg}}{f_{bdg}\,C_{s\text{-}pr}\,\sigma_{yd}} \text{ cm}^3\text{, for point loads}$$

$$Z_{net50} = \frac{\left|\sum \frac{1000 P_i\,S\,l_{bdg}^2}{f_{bdg\text{-}i}} + \sum \frac{1000 F_j\,l_{bdg}}{f_{bdg\text{-}j}}\right|}{C_{s\text{-}pr}\,\sigma_{yd}} \text{ cm}^3,$$

for a combination of loads

where

l_{bdg} = effective bending span, in metres
f_{bdg} = bending moment factor, as given in Table 3.7.2
$C_{s\text{-}pr}$ = permissible bending stress coefficient as given in Table 3.7.1 for design load set given in , for the individual member being considered
i = indices for load component i
j = indices for load component j.

Table 3.7.1 Permissible stress coefficients, $C_{s\text{-}pr}$ and $C_{t\text{-}pr}$, for primary support members

Acceptance criteria set	Permissible bending stress coefficient, $C_{s\text{-}pr}$	Permissible shear stress coefficient, $C_{t\text{-}pr}$
AC1	0,70	0,70
AC2	0,85	0,85
AC3	0,9	0,9

7.3.3.5 For primary support members, the net shear area of the web, $A_{shr\text{-}net50}$, is to be taken as the greatest value for all applicable design load sets, and given by:

$$A_{shr\text{-}net50} = \frac{10 f_{shr}\,|P|\,S\,l_{shr}}{C_{t\text{-}pr}\,\tau_{yd}} \text{ cm}^2\text{, for lateral pressure loads}$$

$$A_{shr\text{-}net50} = \frac{10 f_{shr}\,|F|}{C_{t\text{-}pr}\,\tau_{yd}} \text{ cm}^2\text{, for point loads}$$

$$A_{shr\text{-}net50} = \frac{\left|\sum 10 f_{shr\text{-}i}\,P_i\,s\,l_{shr} + \sum 10 f_{shr\text{-}j}\,F_j\right|}{C_{t\text{-}pr}\,\tau_{yd}} \text{ cm}^2,$$

for a combination of loads

where

l_{shr} = effective shear span, in metres
f_{shr} = shear force factor, as given in Table 3.7.2
$C_{t\text{-}pr}$ = permissible shear stress coefficient as given in Table 3.7.1 for design load set given in Table 3.2.7, for the individual member being considered
i = indices for load component i
j = indices for load component j.

Table 3.7.2 Values of f_{bdg} and f_{shr} (*see continuation*)

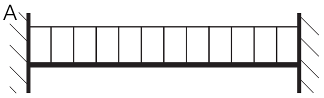
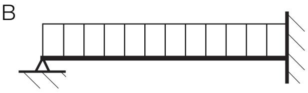
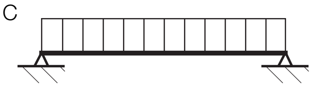
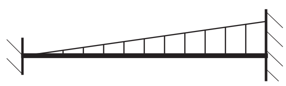
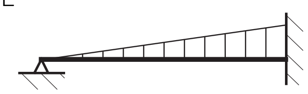
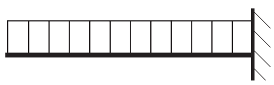
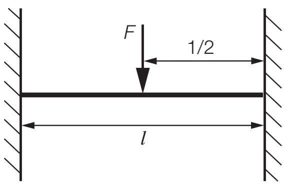
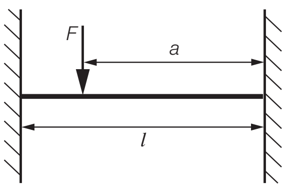
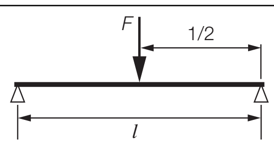
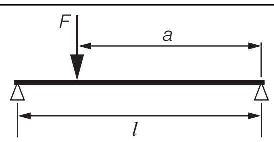
Load and boundary conditions				Bending moment and shear force factor (based on load at mid span where load varies)			Application
Load model		Position, *see* Note 1		1	2	3	
	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} —	f_{bdg3} f_{shr3}	
A				12,0 0,50	24,0 —	12,0 0,50	Built-in at both ends Uniform pressure distribution
B				— 0,38	14,2 —	8,0 0,63	Built-in at one end plus simply supported one end Uniform pressure distribution
C				— 0,50	8,0 —	— 0,50	Simply supported, (both ends are free to rotate) Uniform pressure distribution
D				15,0 0,30	23,3 —	10,0 0,70	Built-in at both ends Linearly varying pressure distribution
E				— 0,20	16,8 —	7,5 0,80	Built-in at one end plus simply supported one end Linearly varying pressure distribution
F				— —	— —	2,0 1,0	Cantilevered beam Uniform pressure distribution
G				8,0 0,5	8,0 —	8,0 0,5	Built-in at both ends Single point load in the centre of the span
H				$\frac{l^3}{a^2 (l-a)}$ $\frac{a^2 (3l-2a)}{l^3}$	$\frac{l^4}{2a^2 (l-a)^2}$ —	$\frac{l^3}{a (l-a)^2}$ $\frac{(l-a)^2 (l+2a)}{l^3}$	Built-in at both ends Single point load, with load anywhere in the span
I				— 0,5	4 —	— 0,5	Simply supported Single point load in the centre of the span
J				—	$\frac{l^2}{a (l-a)}$	—	Simply supported Single point load, load anywhere along the span

Table 3.7.2 **Values of f_{bdg} and f_{shr}** (*conclusion*)

Symbols
l = effective span, l_{bdg} and l_{shr}, as applicable l_{bdg} = effective span in bending, for local or primary support members, in metres l_{shr} = effective span in shear, for local or primary support members, in metres

NOTES

1. The bending moment factor, f_{bdg}, for the support positions is applicable for a distance of 0,2l_{bdg} from the end of the effective bending span for both local and primary support members.
2. The shear force factor, f_{shr}, for the support positions is applicable for a distance of 0,2l_{shr} from the end of the effective shear span for both local and primary support members.
3. Application of f_{bdg} and f_{shr} for local support members:
   (a) the section modulus requirement of local support members is to be determined using the lowest value of f_{bdg1}, f_{bdg2} and f_{bdg3};
   (b) the shear area requirement of local support members is to be determined using the greatest value of f_{shr1} and f_{shr3}.
4. Application of f_{bdg} and f_{shr} for primary support members:
   (a) the section modulus requirement within 0,2l_{bdg} from the end of the effective span is generally to be determined using the applicable f_{bdg1} and f_{bdg3}; however, f_{bdg} is not to be taken greater than 12;
   (b) the section modulus of mid span area is to be determined using f_{bdg} = 24, or f_{bdg2} from the Table if lesser;
   (c) the shear area requirement of end connections within 0,2l_{shr} from the end of the effective span is to be determined using f_{shr} = 0,5 or the applicable f_{shr1} or f_{shr3}, whichever is greater;
   (d) for models A to F, the value of f_{shr} may be gradually reduced outside of 0,2l_{shr} towards 0,5f_{shr} at mid span, where f_{shr} is the greater value of f_{shr1} and f_{shr3}.

■ *Section A1* General

A1.1 Application

A1.1.1 This Appendix contains Dynamic Load Combination Factor (DLCF) Tables for:

- scantling assessment;
- strength assessment by FEM;

as specified in Ch 2,7.1.1 and 8.1.1. An index to the Tables is given in Table A1.1.

The symbols are as defined in Ch 2,6.1 and as follows:

f_{mv} = dynamic load combination factor for vertical wave bending moment

f_{mh} = dynamic load combination factor for horizontal wave bending moment

$f_{v\text{-}mid}$ = dynamic load combination factor for the vertical acceleration of a centre tank

$f_{v\text{-}pt}$ = dynamic load combination factor for the vertical acceleration of a port tank

$f_{v\text{-}stb}$ = dynamic load combination factor for the vertical acceleration of a starboard tank

f_t = dynamic load combination factor for the transverse acceleration of a centre tank

$f_{lng\text{-}mid}$ = dynamic load combination factor for the longitudinal acceleration of a centre tank

$f_{lng\text{-}pt}$ = dynamic load combination factor for the longitudinal acceleration of a port tank

$f_{lng\text{-}stb}$ = dynamic load combination factor for the longitudinal acceleration of a starboard tank

$f_{lng\text{-}ctr}$ = dynamic load combination factor for the longitudinal acceleration of a centre double bottom tank

$f_{ctr\text{-}stb}$ = dynamic load combination factor for dynamic wave pressure at centreline, starboard side

$f_{bilge\text{-}stb}$ = dynamic load combination factor for dynamic wave pressure at bilge, starboard side

$f_{WL\text{-}stb}$ = dynamic load combination factor for dynamic wave pressure at still waterline, starboard side

$f_{ctr\text{-}pt}$ = dynamic load combination factor for dynamic wave pressure at centreline, port side

$f_{bilge\text{-}pt}$ = dynamic load combination factor for dynamic wave pressure at bilge, port side

$f_{WL\text{-}pt}$ = dynamic load combination factor for dynamic wave pressure at still waterline, port side

Table A1.1 Index to Dynamic Load Combination Factor Tables for initial design

Unit size and operating condition	Environment *see* Note 1	Scantling assessment				Strength assessment by FEM
		Draught	Aft end region	Central tank region	Forward end region	
Aframax or VLCC Transit	Unrestricted worldwide	Deep	Table A1.2	Table A1.3	Table A1.4	Table A1.50
		Light	Table A1.5	Table A1.6	Table A1,7	
Aframax Weather vaning	West of Shetland Is.	Deep	Table A1.8	Table A1.9	Table A1.10	Table A1.51
		Light	Table A1.11	Table A1.12	Table A1.13	
	North Sea	Deep	Table A1.14	Table A1.15	Table A1.16	Table A1.52
		Light	Table A1.17	Table A1.18	Table A1.19	
	Brazil Campos Basin	Deep	Table A1.20	Table A1.21	Table A1.22	Table A1.53
		Light	Table A1.23	Table A1.24	Table A1.25	
	Western Australia (non-cyclonic)	Deep	Table A1.26	Table A1.27	Table A1.28	Table A1.54
		Light	Table A1.29	Table A1.30	Table A1.31	
VLCC Weather vaning	Brazil Campos Basin	Deep	Table A1.32	Table A1.33	Table A1.34	Table A1.55
		Light	Table A1.35	Table A1.36	Table A1.37	
	Western Australia (non-cyclonic)	Deep	Table A1.38	Table A1.39	Table A1.40	Table A1.56
		Light	Table A1.41	Table A1.42	Table A1.43	
VLCC Spread moored	Nigeria	Deep	Table A1.44	Table A1.45	Table A1.46	Table A1.57
		Light	Table A1.47	Table A1.48	Table A1.49	

NOTE
The geographic locations of the sites at which long-term environmental data has been used to derive the DLCF Tables are shown in Table 2.3.2 in Chapter 2.

Table A1.2 **Dynamic load cases for aft end region for deep draught condition, unrestricted worldwide transit**

Wave direction	Following sea	Oblique sea		Beam sea			
Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–1,0	–0,7	–0,7	–0,4	–0,4	–0,1	–0,1
$f_{v\text{-}mid}$	0,6	0,9	0,9	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,6	—	0,9	—	1,0	—	0,4
$f_{v\text{-}stb}$	0,6	0,9	—	1,0	—	0,4	—
f_t	0,0	0,2	–0,2	0,5	–0,5	1,0	–1,0
f_{lng}	0,8	0,7	0,7	0,6	0,6	–0,1	–0,1
f_{ctr}	1,0	0,8	0,8	0,7	0,7	0,2	0,2
f_{WL}	0,5	1,0	0,2	0,8	0,3	0,5	–0,3
f_{ctr}	1,0	0,8	0,8	0,7	0,7	0,2	0,2
f_{WL}	0,5	0,2	1,0	0,3	0,8	–0,3	0,5

Table A1.3 **Dynamic load cases for central tank region for deep draught condition, unrestricted worldwide transit**

Wave direction	Head sea		Beam sea					
Max. response	M_{wv}	a_v	a_t		P_{ctr}		P_{WL}	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	1,0	–1,0	–0,1	–0,1	–0,2	–0,2	–0,3	–0,3
f_{mh}	0,0	0,0	–0,1	0,1	0,0	0,0	0,0	0,0
$f_{v\text{-}mid}$	–0,2	0,5	0,5	0,5	1,0	1,0	1,0	1,0
$f_{v\text{-}pt}$	–0,2	0,5	0,2	0,6	0,8	1,0	0,8	1,0
$f_{v\text{-}stb}$	–0,2	0,5	0,6	0,2	1,0	0,8	1,0	0,8
f_t	0,0	0,0	1,0	–1,0	0,5	–0,5	0,6	–0,6
$f_{lng\text{-}mid}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
$f_{lng\text{-}pt}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
$f_{lng\text{-}stb}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
$f_{lng\text{-}ctr}$	0,3	–0,6	–0,1	–0,1	–0,5	–0,5	–0,6	–0,6
$f_{ctr\text{-}stb}$	0,7	–0,6	0,5	0,5	1,0	1,0	0,9	0,9
$f_{bilge\text{-}stb}$	0,3	–0,2	0,8	–0,3	0,9	0,4	1,0	0,4
$f_{WL\text{-}stb}$	0,3	–0,3	0,5	–0,2	0,8	0,4	1,0	0,4
$f_{ctr\text{-}pt}$	0,7	–0,6	0,5	0,5	1,0	1,0	0,9	0,9
$f_{bilge\text{-}pt}$	0,3	–0,2	–0,3	0,8	0,4	0,9	0,4	1,0
$f_{WL\text{-}pt}$	0,3	–0,3	–0,2	0,5	0,4	0,8	0,4	1,0

Table A1.4 Dynamic load cases for forward end region for deep draught condition, unrestricted worldwide transit

Wave direction	Head sea		Oblique sea				Beam Sea	
Max. response	a_v	a_{lng}	P_{bilge}		P_{WL}		a_v	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	–0,7	0,9	–0,3	–0,3	–0,4	–0,4	–0,4	–0,4
f_{mh}	0,0	0,0	0,1	–0,1	0,2	–0,2	–0,1	0,1
$f_{v\text{-}mid}$	0,7	–0,6	0,9	0,9	0,7	0,7	1,0	1,0
$f_{v\text{-}pt}$	0,7	–0,6	0,9	1,0	0,7	0,7	0,9	1,0
$f_{v\text{-}stb}$	0,7	–0,6	1,0	0,9	0,7	0,7	1,0	0,9
f_t	0,0	0,0	0,7	–0,7	0,5	–0,5	0,6	–0,6
$f_{lng\text{-}mid}$	–0,8	1,0	–0,5	–0,5	–1,0	–1,0	–0,5	–0,5
$f_{lng\text{-}pt}$	–0,8	1,0	–0,5	–0,5	–1,0	–0,7	–0,5	–0,5
$f_{lng\text{-}stb}$	–0,8	1,0	–0,5	–0,5	–0,7	–1,0	–0,5	–0,5
$f_{lng\text{-}ctr}$	–0,8	1,0	–0,5	–0,5	–1,0	–1,0	–0,5	–0,5
$f_{ctr\text{-}stb}$	1,0	–0,9	0,8	0,8	0,5	0,5	0,8	0,8
$f_{bilge\text{-}stb}$	0,6	–0,7	1,0	0,5	0,7	0,3	1,0	0,5
$f_{WL\text{-}stb}$	0,3	–0,5	0,9	0,4	1,0	0,2	0,9	0,4
$f_{ctr\text{-}pt}$	1,0	–0,9	0,8	0,8	0,5	0,5	0,8	0,8
$f_{bilge\text{-}pt}$	0,6	–0,7	0,5	1,0	0,3	0,7	0,5	1,0
$f_{WL\text{-}pt}$	0,3	–0,5	0,4	0,9	0,2	1,0	0,4	0,9

Table A1.5 Dynamic load cases for aft end region for light draught condition, unrestricted worldwide transit

Location	Aft end region						
Wave direction	Following sea	Oblique sea		Beam sea			
Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–1,0	–0,3	–0,3	0,2	0,2	0,1	0,1
$f_{v\text{-}mid}$	0,6	0,9	0,9	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,6	—	0,9	—	1,0	—	0,5
$f_{v\text{-}stb}$	0,6	0,9	—	1,0	—	0,5	—
f_t	0,0	0,1	–0,1	0,6	–0,6	1,0	–1,0
f_{lng}	0,7	0,8	0,8	0,2	0,2	0,0	0,0
f_{ctr}	1,0	0,7	0,7	0,5	0,5	0,1	0,1
f_{WL}	0,8	1,0	0,3	0,6	0,1	0,4	–0,3
f_{ctr}	1,0	0,7	0,7	0,5	0,5	0,1	0,1
f_{WL}	0,8	0,3	1,0	0,1	0,6	–0,3	0,4

Table A1.6 Dynamic load cases for central tank region for light draught condition, unrestricted worldwide transit

Wave direction	Head sea		Beam sea					
Max. response	M_{wv}	a_v	a_t		P_{ctr}		P_{WL}	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	1,0	–1,0	–0,1	–0,1	–0,2	–0,2	–0,2	–0,2
f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,2	0,2
$f_{v\text{-}mid}$	–0,1	0,4	0,5	0,5	1,0	1,0	1,0	1,0
$f_{v\text{-}pt}$	–0,1	0,4	0,1	0,8	0,7	1,0	0,6	1,0
$f_{v\text{-}stb}$	–0,1	0,4	0,8	0,1	1,0	0,7	1,0	0,6
f_t	0,0	0,0	1,0	–1,0	0,8	–0,8	0,6	–0,6
$f_{lng\text{-}mid}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{lng\text{-}pt}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{lng\text{-}stb}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{lng\text{-}ctr}$	0,2	–0,1	0,0	0,0	–0,2	–0,2	–0,1	–0,1
$f_{ctr\text{-}stb}$	1,0	–0,8	0,3	0,3	0,8	0,8	0,4	0,4
$f_{bilge\text{-}stb}$	0,3	–0,2	0,9	–0,4	0,9	0,3	0,9	0,2
$f_{WL\text{-}stb}$	0,3	–0,2	0,7	–0,4	0,9	0,2	1,0	0,2
$f_{ctr\text{-}pt}$	1,0	–0,8	0,3	0,3	0,8	0,8	0,4	0,4
$f_{bilge\text{-}pt}$	0,3	–0,2	–0,4	0,9	0,3	0,9	0,2	0,9
$f_{WL\text{-}pt}$	0,3	–0,2	–0,4	0,7	0,2	0,7	0,2	1,0

Table A1.7 Dynamic load cases for forward end region for light draught condition, unrestricted worldwide transit

Wave direction	Head sea		Oblique sea				Beam sea	
Max. response	a_v	a_{lng}	P_{bilge}		P_{WL}		a_v	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P
f_{mv}	–0,8	0,9	–0,2	–0,2	–0,3	–0,3	–0,1	–0,1
f_{mh}	0,0	0,0	–0,5	0,5	0,3	–0,3	–0,4	0,4
$f_{v\text{-}mid}$	0,7	–0,6	0,6	0,6	0,9	0,9	1,0	1,0
$f_{v\text{-}pt}$	0,7	–0,6	0,3	0,8	0,7	0,7	0,5	1,0
$f_{v\text{-}stb}$	0,7	–0,6	0,8	0,3	0,7	0,7	1,0	0,5
f_t	0,0	0,0	0,9	–0,9	0,2	–0,2	0,7	–0,7
$f_{lng\text{-}mid}$	–0,9	1,0	–0,3	–0,3	–0,9	–0,9	0,0	0,0
$f_{lng\text{-}pt}$	–0,9	1,0	–0,5	0,2	–0,9	–0,6	0,0	0,0
$f_{lng\text{-}stb}$	–0,9	1,0	0,2	–0,5	–0,6	–0,9	0,0	0,0
$f_{lng\text{-}ctr}$	–0,9	1,0	–0,3	–0,3	–0,9	–0,9	0,0	0,0
$f_{ctr\text{-}stb}$	1,0	–0,7	0,6	0,6	0,6	0,6	0,4	0,4
$f_{bilge\text{-}stb}$	0,5	–0,4	1,0	–0,3	0,9	0,2	0,8	0,2
$f_{WL\text{-}stb}$	0,3	–0,2	0,9	–0,3	1,0	0,1	0,8	0,2
$f_{ctr\text{-}pt}$	1,0	–0,7	0,6	0,6	0,6	0,6	0,4	0,4
$f_{bilge\text{-}pt}$	0,5	–0,4	–0,3	1,0	0,2	0,9	0,2	0,8
$f_{WL\text{-}pt}$	0,3	–0,2	–0,3	0,9	0,1	1,0	0,2	0,8

Table A1.8 **Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.**

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,5	–0,2	–0,2	0,5	0,5	0,1	0,1
f_{mh}	–0,7	0,3	–0,3	0,7	–0,7	0,3	–0,3
$f_{v\text{-}mid}$	–1,0	–0,3	–0,3	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	–1,0	–0,3	–0,3	1,0	1,0	0,1	0,3
$f_{v\text{-}stb}$	–1,0	–0,3	–0,3	1,0	1,0	0,3	0,1
f_t	0,2	0,0	0,0	–0,2	0,2	1,0	–1,0
$f_{lng\text{-}mid}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{lng\text{-}pt}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{lng\text{-}stb}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{lng\text{-}ctr}$	–0,8	–0,4	–0,4	0,8	0,8	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,5	0,5	–1,0	–1,0	–0,3	–0,3
$f_{bilge\text{-}stb}$	1,0	0,5	0,7	–0,9	–0,7	–0,8	0,4
$f_{WL\text{-}stb}$	0,7	1,0	1,0	–0,7	–0,4	–0,6	0,4
$f_{ctr\text{-}pt}$	1,0	0,5	0,5	–1,0	–1,0	–0,3	–0,3
$f_{bilge\text{-}pt}$	1,0	0,7	0,5	–0,7	–0,9	0,4	–0,8
$f_{WL\text{-}pt}$	0,7	1,0	1,0	–0,4	–0,7	0,4	–0,6

Table A1.9 **Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.**

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,4	–0,6	–0,2	–0,2	0,1	0,1	0,8	0,8	–0,2	–0,2
f_{mh}	–0,1	0,2	0,3	–1,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0
$f_{v\text{-}mid}$	0,5	1,0	–0,6	–0,1	–0,1	0,3	0,3	0,1	0,1	–0,1	–0,1
$f_{v\text{-}pt}$	0,5	1,0	–0,6	–0,1	–0,1	0,1	0,5	0,1	0,1	–0,1	–0,1
$f_{v\text{-}stb}$	0,5	1,0	–0,6	–0,1	–0,1	0,5	0,1	0,1	0,1	–0,1	–0,1
f_t	0,0	0,2	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,6	0,1	1,0	0,4	0,4	0,0	0,0	–0,3	–0,3	0,4	0,4
$f_{lng\text{-}pt}$	–0,6	0,1	1,0	0,4	0,4	–0,1	0,1	–0,3	–0,3	0,4	0,4
$f_{lng\text{-}stb}$	–0,6	0,1	1,0	0,4	0,4	0,1	–0,1	–0,3	–0,3	0,4	0,4
$f_{lng\text{-}ctr}$	–0,6	0,1	1,0	0,4	0,4	0,0	0,0	–0,3	–0,3	0,4	0,4
$f_{ctr\text{-}stb}$	1,0	–1,0	–0,2	–0,3	–0,3	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}stb}$	0,5	–1,0	–0,1	–0,4	0,1	–1,0	0,6	0,7	0,6	0,4	0,4
$f_{WL\text{-}stb}$	0,8	–0,7	–0,2	–0,3	0,1	–0,8	0,7	1,0	0,9	0,9	1,0
$f_{ctr\text{-}pt}$	1,0	–1,0	–0,2	–0,3	–0,3	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}pt}$	0,5	–1,0	–0,1	0,1	–0,4	0,6	–1,0	0,6	0,7	0,4	0,4
$f_{WL\text{-}pt}$	0,8	–0,7	–0,2	0,1	–0,3	0,7	–0,8	0,9	1,0	1,0	0,9

Table A1.10 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,7	–0,8	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
f_{mh}	0,1	0,0	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,0	0,0
$f_{v\text{-}pt}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,1	–0,1
f_t	0,1	0,0	0,0	0,0	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,9	0,9	–0,1	0,1
$f_{bilge\text{-}stb}$	–1,0	0,8	0,9	0,8	0,8	1,0	0,8	0,8	–0,5	0,4
$f_{WL\text{-}stb}$	–0,5	0,5	0,8	0,7	0,7	0,8	1,0	1,0	–0,5	0,4
$f_{ctr\text{-}pt}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,9	0,9	0,1	–0,1
$f_{bilge\text{-}pt}$	–1,0	0,8	0,8	0,9	1,0	0,8	0,8	0,8	0,4	–0,5
$f_{WL\text{-}pt}$	–0,5	0,5	0,7	0,8	0,8	0,7	1,0	1,0	0,4	–0,5

Table A1.11 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,1	–0,1	–0,1	0,4	0,4	0,3	0,3
f_{mh}	0,0	0,0	0,0	0,0	0,0	–0,8	0,8
$f_{v\text{-}mid}$	–0,5	–0,3	–0,3	1,0	1,0	0,5	0,5
$f_{v\text{-}pt}$	–0,5	–0,3	–0,3	1,0	1,0	0,4	0,6
$f_{v\text{-}stb}$	–0,5	–0,3	–0,3	1,0	1,0	0,6	0,4
f_t	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
$f_{lng\text{-}mid}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
$f_{lng\text{-}pt}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
$f_{lng\text{-}stb}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
$f_{lng\text{-}ctr}$	–0,2	–0,6	–0,6	–0,4	–0,4	0,2	0,2
$f_{ctr\text{-}stb}$	1,0	0,5	0,5	–0,4	–0,4	–0,8	–0,4
$f_{bilge\text{-}stb}$	1,0	0,5	0,5	–0,1	–0,1	–0,9	0,5
$f_{WL\text{-}stb}$	1,0	1,0	1,0	0,1	0,1	–0,8	0,6
$f_{ctr\text{-}pt}$	1,0	0,5	0,5	–0,4	–0,4	–0,4	–0,8
$f_{bilge\text{-}pt}$	1,0	0,5	0,5	–0,1	–0,1	0,5	–0,9
$f_{WL\text{-}pt}$	1,0	1,0	1,0	0,1	0,1	0,6	–0,8

Table A1.12 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,1	–0,4	–0,4	–0,4	0,2	0,2	0,8	0,8	0,5	0,5
f_{mh}	–0,6	0,0	0,0	–1,0	1,0	–0,8	0,8	0,0	0,0	0,0	0,0
$f_{v\text{-}mid}$	0,3	1,0	–0,5	–0,5	–0,5	0,3	0,3	0,1	0,1	–0,5	–0,5
$f_{v\text{-}pt}$	0,3	1,0	–0,5	–0,5	–0,5	0,1	0,5	0,1	0,1	–0,5	–0,5
$f_{v\text{-}stb}$	0,3	1,0	–0,5	–0,5	–0,5	0,5	0,1	0,1	0,1	–0,5	–0,5
f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
$f_{lng\text{-}pt}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
$f_{lng\text{-}stb}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
$f_{lng\text{-}ctr}$	–0,4	–1,0	1,0	0,9	0,9	0,1	0,1	–0,3	–0,3	0,3	0,3
$f_{ctr\text{-}stb}$	1,0	–0,4	–0,4	–0,4	–0,4	0,0	0,0	1,0	1,0	0,9	0,9
$f_{bilge\text{-}stb}$	0,6	–0,5	–0,2	–0,6	0,2	–0,7	0,7	0,7	0,6	0,7	0,8
$f_{WL\text{-}stb}$	0,8	–0,9	–0,1	–0,2	0,3	–0,5	0,7	0,8	0,8	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,4	–0,4	–0,4	–0,4	0,0	0,0	1,0	1,0	0,9	0,9
$f_{bilge\text{-}pt}$	0,6	–0,5	–0,2	0,2	–0,6	0,7	–0,7	0,6	0,7	0,8	0,7
$f_{WL\text{-}pt}$	0,8	–0,9	–0,1	0,3	–0,2	0,7	–0,5	0,8	0,8	1,0	1,0

Table A1.13 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, west of Shetland Is.

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,8	–0,8	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
f_{mh}	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	0,0	0,0
$f_{v\text{-}pt}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–0,8	–0,9	–0,9	–0,9	–0,9	–0,4	–0,4	0,1	–0,1
f_t	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	0,9	0,9	1,0	1,0	0,6	0,6	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,7	1,0	1,0	1,0	1,0	0,9	0,9	0,0	0,0
$f_{bilge\text{-}stb}$	–0,7	0,6	0,8	0,8	1,0	1,0	0,8	0,8	–0,7	0,6
$f_{WL\text{-}stb}$	–0,5	0,4	0,7	0,8	1,0	0,9	1,0	1,0	–0,6	0,5
$f_{ctr\text{-}pt}$	–0,9	0,7	1,0	1,0	1,0	1,0	0,9	0,9	0,0	0,0
$f_{bilge\text{-}pt}$	–0,7	0,6	0,8	0,8	1,0	1,0	0,8	0,8	0,6	–0,7
$f_{WL\text{-}pt}$	–0,5	0,4	0,8	0,7	0,9	1,0	1,0	1,0	0,5	–0,6

Table A1.14 **Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, North Sea**

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,4	–0,2	–0,2	0,3	0,3	0,1	0,1
f_{mh}	–0,1	–0,3	0,3	–0,3	0,3	–0,1	0,1
$f_{v\text{-}mid}$	–1,0	–0,1	–0,1	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	–1,0	–0,1	–0,1	1,0	1,0	0,1	0,3
$f_{v\text{-}stb}$	–1,0	–0,1	–0,1	1,0	1,0	0,3	0,1
f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
$f_{lng\text{-}pt}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
$f_{lng\text{-}stb}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
$f_{lng\text{-}ctr}$	–0,1	0,1	0,1	0,2	0,2	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,7	0,7	–1,0	–1,0	–0,3	–0,1
$f_{bilge\text{-}stb}$	0,9	0,6	0,6	–0,9	–0,7	–0,7	0,5
$f_{WL\text{-}stb}$	0,7	1,0	1,0	–0,7	–0,3	–0,5	0,5
$f_{ctr\text{-}pt}$	1,0	0,7	0,7	–1,0	–1,0	–0,1	–0,3
$f_{bilge\text{-}pt}$	0,9	0,6	0,6	–0,7	–0,9	0,5	–0,7
$f_{WL\text{-}pt}$	0,7	1,0	1,0	–0,3	–0,7	0,5	–0,5

Table A1.15 **Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, North Sea**

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,3	–0,6	–0,3	–0,3	0,1	0,1	0,6	0,6	–0,2	–0,2
f_{mh}	–0,3	–0,1	–0,3	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,7	1,0	–0,8	–0,3	–0,3	0,3	0,3	0,1	0,1	–0,2	–0,2
$f_{v\text{-}pt}$	0,7	1,0	–0,8	–0,3	–0,3	0,1	0,4	0,1	0,1	–0,2	–0,2
$f_{v\text{-}stb}$	0,7	1,0	–0,8	–0,3	–0,3	0,4	0,1	0,1	0,1	–0,2	–0,2
f_t	0,1	0,3	0,1	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
$f_{lng\text{-}pt}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
$f_{lng\text{-}stb}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
$f_{lng\text{-}ctr}$	–0,9	–0,1	1,0	0,4	0,4	0,0	0,0	–0,2	–0,2	0,4	0,4
$f_{ctr\text{-}stb}$	1,0	–0,9	–0,2	–0,2	–0,1	–0,4	–0,1	1,0	1,0	0,4	0,4
$f_{bilge\text{-}stb}$	0,6	–0,9	–0,1	–0,3	0,2	–0,9	0,8	0,6	0,7	0,5	0,5
$f_{WL\text{-}stb}$	0,8	–0,5	–0,2	–0,2	0,1	–0,6	0,6	0,8	0,9	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,9	–0,2	–0,1	–0,2	–0,1	–0,4	1,0	1,0	0,4	0,4
$f_{bilge\text{-}pt}$	0,6	–0,9	–0,1	0,2	–0,3	0,8	–0,9	0,7	0,6	0,5	0,5
$f_{WL\text{-}pt}$	0,8	–0,5	–0,2	0,1	–0,2	0,6	–0,6	0,9	0,8	1,0	1,0

Table A1.16 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, North Sea

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,1	0,1
f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,0	0,0
$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,1	–0,1
f_t	0,0	0,0	0,0	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,9	1,0	1,0	1,0	1,0	0,8	0,8	0,0	0,0
$f_{bilge\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	–0,4	0,4
$f_{WL\text{-}stb}$	–0,8	0,8	1,0	0,9	1,0	0,9	1,0	1,0	–0,4	0,4
$f_{ctr\text{-}pt}$	–0,9	0,9	1,0	1,0	1,0	1,0	0,8	0,8	0,0	0,0
$f_{bilge\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,8	0,8	0,4	–0,4
$f_{WL\text{-}pt}$	–0,8	0,8	0,9	1,0	0,9	1,0	1,0	1,0	0,4	–0,4

Table A1.17 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, North Sea

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,2	0,1	0,1	0,5	0,5	0,1	0,1
f_{mh}	–0,2	–0,1	0,1	–0,2	0,2	–0,8	0,8
$f_{v\text{-}mid}$	0,1	–0,4	–0,4	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,1	–0,4	–0,4	1,0	1,0	0,1	0,4
$f_{v\text{-}stb}$	0,1	–0,4	–0,4	1,0	1,0	0,4	0,1
f_t	0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{lng\text{-}pt}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{lng\text{-}stb}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{lng\text{-}ctr}$	–0,5	–0,8	–0,8	1,0	1,0	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	0,4	0,4	–0,6	–0,6	0,0	0,0
$f_{bilge\text{-}stb}$	–1,0	0,6	0,3	–0,1	–0,2	–0,8	0,8
$f_{WL\text{-}stb}$	–1,0	1,0	0,8	0,1	–0,1	–0,8	0,8
$f_{ctr\text{-}pt}$	–1,0	0,4	0,4	–0,6	–0,6	0,0	0,0
$f_{bilge\text{-}pt}$	–1,0	0,3	0,6	–0,2	–0,1	0,8	–0,8
$f_{WL\text{-}pt}$	–1,0	0,8	1,0	–0,1	0,1	0,8	–0,8

Table A1.18 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, North Sea

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,4	–0,5	–0,7	–0,7	0,1	0,1	0,7	0,7	0,4	0,4
f_{mh}	–0,2	–0,8	0,6	–1,0	1,0	–0,8	0,8	–0,2	0,2	–0,2	0,2
$f_{v\text{-}mid}$	0,2	1,0	–0,4	–0,9	–0,9	0,3	0,3	–0,1	–0,1	–0,6	–0,6
$f_{v\text{-}pt}$	0,2	1,0	–0,4	–0,9	–0,9	0,1	0,5	–0,1	–0,1	–0,6	–0,6
$f_{v\text{-}stb}$	0,2	1,0	–0,4	–0,9	–0,9	0,5	0,1	–0,1	–0,1	–0,6	–0,6
f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{lng\text{-}pt}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{lng\text{-}stb}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{lng\text{-}ctr}$	–0,6	–1,0	1,0	1,0	1,0	0,1	0,1	–0,2	–0,2	0,7	0,7
$f_{ctr\text{-}stb}$	1,0	–0,1	–0,5	–0,7	–0,5	–0,4	0,2	1,0	1,0	0,9	0,9
$f_{bilge\text{-}stb}$	0,6	–0,6	–0,4	–0,7	0,2	–0,8	0,8	0,7	0,4	0,7	0,5
$f_{WL\text{-}stb}$	0,8	–1,0	–0,3	–0,2	0,4	–0,8	0,8	0,7	0,7	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,1	–0,5	–0,5	–0,7	0,2	–0,4	1,0	1,0	0,9	0,9
$f_{bilge\text{-}pt}$	0,6	–0,6	–0,4	0,2	–0,7	0,8	–0,8	0,4	0,7	0,5	0,7
$f_{WL\text{-}pt}$	0,8	–1,0	–0,3	0,4	–0,2	0,8	–0,8	0,7	0,7	1,0	1,0

Table A1.19 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, North Sea

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,9	–0,9	0,1	0,1
f_{mh}	0,1	0,1	–0,1	0,1	0,0	0,0	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	0,0	0,0
$f_{v\text{-}pt}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	–0,1	0,2
$f_{v\text{-}stb}$	1,0	–0,9	–0,9	–0,9	–1,0	–1,0	–0,5	–0,5	0,2	0,1
f_t	–0,1	0,1	0,1	–0,1	0,1	–0,1	0,0	0,0	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,8	0,8	–0,3	0,1
$f_{bilge\text{-}stb}$	–0,9	0,8	0,9	0,5	0,6	1,0	0,8	0,4	–0,8	0,7
$f_{WL\text{-}stb}$	–0,6	0,6	0,9	0,5	0,5	0,9	1,0	0,7	–0,8	0,7
$f_{ctr\text{-}pt}$	–0,9	0,8	1,0	1,0	1,0	1,0	0,8	0,8	0,1	–0,3
$f_{bilge\text{-}pt}$	–0,9	0,8	0,5	0,9	1,0	0,6	0,4	0,8	0,7	–0,8
$f_{WL\text{-}pt}$	–0,6	0,6	0,5	0,9	0,9	0,5	0,7	1,0	0,7	–0,8

Table A1.20 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,4	–0,1	–0,1	0,4	0,4	0,2	0,2
f_{mh}	–0,4	–0,1	0,1	–0,4	0,4	–0,1	0,1
$f_{v\text{-}mid}$	–1,0	0,1	0,1	1,0	1,0	0,4	0,4
$f_{v\text{-}pt}$	–1,0	0,1	0,1	1,0	1,0	0,2	0,5
$f_{v\text{-}stb}$	–1,0	0,1	0,1	1,0	1,0	0,5	0,2
f_t	0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{lng\text{-}pt}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{lng\text{-}stb}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{lng\text{-}ctr}$	–0,4	0,4	0,4	0,4	0,4	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,2	0,2	–1,0	–1,0	0,0	0,0
$f_{bilge\text{-}stb}$	0,6	0,2	0,2	–0,6	–0,6	–0,8	0,7
$f_{WL\text{-}stb}$	0,5	1,0	1,0	–0,4	–0,3	–0,7	0,7
$f_{ctr\text{-}pt}$	1,0	0,2	0,2	–1,0	–1,0	0,0	0,0
$f_{bilge\text{-}pt}$	0,6	0,2	0,2	–0,6	–0,6	0,7	–0,8
$f_{WL\text{-}pt}$	0,3	1,0	1,0	–0,3	–0,4	0,7	–0,7

Table A1.21 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,4	–0,6	–0,2	–0,2	0,1	0,1	–0,4	–0,4	–0,3	–0,3
f_{mh}	–0,4	0,2	0,7	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,5	1,0	–0,5	–0,1	–0,1	0,4	0,4	–1,0	–1,0	–0,2	–0,2
$f_{v\text{-}pt}$	0,5	1,0	–0,5	–0,1	–0,1	0,1	0,6	–1,0	–1,0	–0,2	–0,2
$f_{v\text{-}stb}$	0,5	1,0	–0,5	–0,1	–0,1	0,6	0,1	–1,0	–1,0	–0,2	–0,2
f_t	0,1	0,2	–0,1	0,1	–0,1	1,0	–1,0	0,2	–0,2	0,0	0,0
$f_{lng\text{-}mid}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{lng\text{-}pt}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{lng\text{-}stb}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{lng\text{-}ctr}$	–1,0	–0,1	1,0	0,4	0,4	0,1	0,1	0,1	0,1	0,3	0,3
$f_{ctr\text{-}stb}$	0,7	–0,9	–0,2	–0,2	–0,2	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}stb}$	0,3	–0,6	–0,1	–0,2	0,1	–0,9	0,9	0,6	0,5	0,3	0,3
$f_{WL\text{-}stb}$	0,6	–0,5	0,2	–0,2	0,1	–0,9	0,9	0,5	0,2	1,0	1,0
$f_{ctr\text{-}pt}$	0,7	–0,9	–0,2	–0,2	–0,2	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}pt}$	0,3	–0,6	–0,1	0,1	–0,2	0,9	–0,9	0,5	0,6	0,3	0,3
$f_{WL\text{-}pt}$	0,6	–0,5	0,2	0,1	–0,2	0,9	–0,9	0,2	0,5	1,0	1,0

Table A1.22 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,9	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	0,1	0,1
f_{mh}	0,0	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,0	0,0
$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	–0,1	0,2
$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,8	–0,8	0,2	–0,1
f_t	0,0	0,0	0,1	–0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	1,0	0,9	–0,2	0,1
$f_{bilge\text{-}stb}$	–0,9	0,9	0,9	0,9	0,9	1,0	0,8	0,9	–0,7	0,7
$f_{WL\text{-}stb}$	–0,8	0,8	0,9	0,7	0,9	0,9	1,0	1,0	–0,7	0,7
$f_{ctr\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,9	1,0	0,1	–0,2
$f_{bilge\text{-}pt}$	–0,9	0,9	0,9	0,9	1,0	0,9	0,9	0,8	0,7	–0,7
$f_{WL\text{-}pt}$	–0,8	0,8	0,7	0,9	0,9	0,9	1,0	1,0	0,7	–0,7

Table A1.23 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,2	–0,3	–0,3	–0,2	–0,2	–0,1	–0,1
f_{mh}	–0,1	–0,1	0,1	–0,2	0,2	–0,8	0,8
$f_{v\text{-}mid}$	0,4	–0,5	–0,5	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	0,4	–0,5	–0,5	1,0	1,0	–0,1	0,4
$f_{v\text{-}stb}$	0,4	–0,5	–0,5	1,0	1,0	0,4	–0,1
f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{lng\text{-}pt}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{lng\text{-}stb}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{lng\text{-}ctr}$	0,1	–1,0	–1,0	0,7	0,7	–0,1	–0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	1,0	–0,6	–0,7	–0,7	0,4
$f_{bilge\text{-}stb}$	–0,5	0,5	0,5	–0,4	–0,4	–0,8	0,8
$f_{WL\text{-}stb}$	–0,7	1,0	1,0	–0,3	–0,1	–0,8	0,8
$f_{ctr\text{-}pt}$	–1,0	1,0	1,0	–0,7	–0,6	0,4	–0,7
$f_{bilge\text{-}pt}$	–0,5	0,5	0,5	–0,4	–0,4	0,8	–0,8
$f_{WL\text{-}pt}$	–0,7	1,0	1,0	–0,1	–0,3	0,8	–0,8

Table A1.24 **Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin**

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	–0,1	–0,5	–0,8	–0,8	–0,1	–0,1	0,7	0,7	0,5	0,5
f_{mh}	–0,1	–0,1	–0,2	–1,0	1,0	–0,8	0,8	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,1	1,0	–0,3	–0,5	–0,5	0,2	0,2	–0,1	–0,1	–0,5	–0,5
$f_{v\text{-}pt}$	0,1	1,0	–0,3	–0,5	–0,5	–0,1	0,5	–0,1	–0,1	–0,5	–0,5
$f_{v\text{-}stb}$	0,1	1,0	–0,3	–0,5	–0,5	0,5	–0,1	–0,1	–0,1	–0,5	–0,5
f_t	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{lng\text{-}pt}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{lng\text{-}stb}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{lng\text{-}ctr}$	–0,5	–0,1	1,0	0,7	0,7	0,1	0,1	–0,1	–0,1	1,0	1,0
$f_{ctr\text{-}stb}$	1,0	–0,7	–0,5	–0,9	–0,9	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}stb}$	0,3	–0,4	–0,2	–0,6	0,2	–0,8	0,8	0,4	0,4	0,6	0,6
$f_{WL\text{-}stb}$	0,5	–0,3	–0,1	–0,4	0,4	–0,8	0,8	0,5	0,5	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,7	–0,5	–0,9	–0,9	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}pt}$	0,3	–0,4	–0,2	0,2	–0,6	0,8	–0,8	0,4	0,4	0,6	0,6
$f_{WL\text{-}pt}$	0,5	–0,3	–0,1	0,4	–0,4	0,8	–0,8	0,5	0,5	1,0	1,0

Table A1.25 **Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Brazil Campos Basin**

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–0,6	–0,6	–0,1	–0,1
f_{mh}	–0,1	–0,1	–0,1	0,1	0,0	0,0	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	0,2	0,2
$f_{v\text{-}pt}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	–0,1	0,4
$f_{v\text{-}stb}$	1,0	–0,9	–0,8	–0,8	–1,0	–1,0	–0,6	–0,6	0,4	–0,1
f_t	0,1	0,1	0,1	–0,1	0,1	0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	0,9	0,9	–1,0	–1,0	0,6	0,6	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,0	0,0
$f_{bilge\text{-}stb}$	–0,5	0,4	0,5	0,4	1,0	0,6	0,5	0,5	–0,8	0,8
$f_{WL\text{-}stb}$	–0,4	0,3	0,5	0,4	1,0	0,6	1,0	0,8	–0,8	0,8
$f_{ctr\text{-}pt}$	–1,0	0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,0	0,0
$f_{bilge\text{-}pt}$	–0,5	0,4	0,4	0,5	0,6	1,0	0,5	0,5	0,8	–0,8
$f_{WL\text{-}pt}$	–0,4	0,3	0,4	0,5	0,6	1,0	0,8	1,0	0,8	–0,8

Table A1.26 Dynamic load cases for aft region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	1,0	–0,3	–0,3	0,5	0,5	0,2	0,2
f_{mh}	–0,1	–0,9	0,9	–0,5	0,5	0,0	0,0
$f_{v\text{-}mid}$	0,4	–0,2	–0,2	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,4	–0,2	–0,2	1,0	1,0	0,2	0,4
$f_{v\text{-}stb}$	0,4	–0,2	–0,2	1,0	1,0	0,4	0,2
f_t	–0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
$f_{lng\text{-}pt}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
$f_{lng\text{-}stb}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
$f_{lng\text{-}ctr}$	0,1	0,2	0,2	0,7	0,7	0,1	0,1
$f_{ctr\text{-}stb}$	–0,1	0,6	0,6	–0,9	–0,9	–0,4	–0,2
$f_{bilge\text{-}stb}$	–0,1	0,6	0,3	–0,7	–0,7	–0,6	0,5
$f_{WL\text{-}stb}$	–0,2	1,0	0,9	–0,5	–0,2	–0,5	0,5
$f_{ctr\text{-}pt}$	–0,1	0,6	0,6	–0,9	–0,9	–0,2	–0,4
$f_{bilge\text{-}pt}$	–0,1	0,3	0,6	–0,7	–0,7	0,5	–0,6
$f_{WL\text{-}pt}$	–0,2	0,9	1,0	–0,2	–0,5	0,5	–0,5

Table A1.27 Dynamic load cases for central tank region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
Global loads	1,0	0,8	–0,5	–0,4	–0,4	0,2	0,2	–0,5	–0,5	–0,3	–0,3
	–0,1	–0,1	–0,5	–1,0	1,0	–0,1	0,1	–0,1	0,1	–0,2	0,2
Accelerations	0,4	1,0	–0,3	–0,2	–0,2	0,3	0,3	–1,0	–1,0	–0,1	–0,1
	0,4	1,0	–0,3	–0,2	–0,2	0,1	0,4	–1,0	–1,0	–0,1	–0,1
	0,4	1,0	–0,3	–0,2	–0,2	0,4	0,1	–1,0	–1,0	–0,1	–0,1
	0,1	0,1	0,0	0,1	–0,1	1,0	–1,0	0,3	–0,3	0,0	0,0
	–0,3	0,3	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
	–0,3	0,4	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
	–0,3	0,2	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
	–0,3	0,3	1,0	0,6	0,6	–0,1	–0,1	0,1	0,1	0,5	0,5
Dynamic wave pressure for starboard side	0,4	–0,8	–0,2	–0,2	–0,2	–0,3	–0,1	1,0	1,0	0,2	0,2
	0,2	–0,6	–0,2	–0,3	0,2	–0,8	0,8	0,8	0,7	0,5	0,2
	0,4	–0,3	–0,2	–0,3	0,1	–0,7	0,7	0,7	0,3	1,0	1,0
Dynamic wave pressure for port side	0,4	–0,8	–0,2	–0,2	–0,2	–0,1	–0,3	1,0	1,0	0,2	0,2
	0,2	–0,6	–0,2	0,2	–0,3	0,8	–0,8	0,7	0,8	0,2	0,5
	0,4	–0,3	–0,2	0,1	–0,3	0,7	–0,7	0,3	0,7	1,0	1,0

Table A1.28 Dynamic load cases for forward end region for deep draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,8	–0,8	–0,9	–0,9	–1,0	–1,0	–0,4	–0,4	0,1	0,1
f_{mh}	–0,1	–0,1	–0,1	0,1	–0,1	0,1	–0,3	0,3	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	0,0	0,0
$f_{v\text{-}pt}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	–0,1	0,1
$f_{v\text{-}stb}$	1,0	–1,0	–1,0	–1,0	–1,0	–1,0	–0,1	–0,1	0,1	–0,1
f_t	0,1	0,1	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{lng\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,1	0,1	0,1	0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,3	0,3	0,0	0,0
$f_{bilge\text{-}stb}$	–1,0	0,9	1,0	0,7	1,0	1,0	0,3	0,3	–0,5	0,5
$f_{WL\text{-}stb}$	–0,4	0,4	0,3	0,5	0,5	0,6	1,0	0,6	–0,5	0,4
$f_{ctr\text{-}pt}$	–1,0	1,0	1,0	1,0	1,0	1,0	0,3	0,3	0,0	0,0
$f_{bilge\text{-}pt}$	–1,0	0,9	0,7	1,0	1,0	1,0	0,3	0,3	0,5	–0,5
$f_{WL\text{-}pt}$	–0,4	0,4	0,5	0,3	0,6	0,5	0,6	1,0	0,4	–0,5

Table A1.29 Dynamic load cases for aft region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–1,0	0,1	0,1	0,8	0,8	0,1	0,1
f_{mh}	0,0	0,0	0,0	–0,1	0,1	–0,8	0,8
$f_{v\text{-}mid}$	–0,7	–0,4	–0,4	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	–0,7	–0,4	–0,4	1,0	1,0	0,1	0,3
$f_{v\text{-}stb}$	–0,7	–0,4	–0,4	1,0	1,0	0,3	0,1
f_t	0,1	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{lng\text{-}pt}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{lng\text{-}stb}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{lng\text{-}ctr}$	–0,4	–0,8	–0,8	0,9	0,9	0,1	0,1
$f_{ctr\text{-}stb}$	1,0	0,4	0,4	–0,9	–0,9	–0,5	–0,5
$f_{bilge\text{-}stb}$	0,3	0,5	0,5	–0,2	–0,2	–0,7	0,6
$f_{WL\text{-}stb}$	0,2	1,0	1,0	–0,1	–0,1	–0,7	0,7
$f_{ctr\text{-}pt}$	1,0	0,4	0,4	–0,9	–0,9	–0,5	–0,5
$f_{bilge\text{-}pt}$	0,3	0,5	0,5	–0,2	–0,2	0,6	–0,7
$f_{WL\text{-}pt}$	0,2	1,0	1,0	–0,1	–0,1	0,7	–0,7

Table A1.30 Dynamic load cases for central tank region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,1	–0,5	0,1	0,1	0,1	0,1	0,9	0,9	–0,3	–0,3
f_{mh}	0,0	0,1	0,0	–1,0	1,0	–0,7	0,7	–0,1	0,1	0,0	0,0
$f_{v\text{-mid}}$	0,3	1,0	–0,3	0,3	0,3	0,1	0,1	0,2	0,2	–0,3	–0,3
$f_{v\text{-pt}}$	0,3	1,0	–0,3	0,5	0,5	–0,1	0,3	0,2	0,2	–0,3	–0,3
$f_{v\text{-stb}}$	0,3	1,0	–0,3	0,1	0,1	0,3	–0,1	0,2	0,2	–0,3	–0,3
f_t	0,0	–0,1	0,0	1,0	–1,0	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-mid}}$	–0,1	–0,2	1,0	0,0	0,0	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{lng\text{-pt}}$	–0,1	–0,2	1,0	–0,1	0,1	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{lng\text{-stb}}$	–0,1	–0,2	1,0	0,1	–0,1	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{lng\text{-ctr}}$	–0,1	–0,2	1,0	0,0	0,0	0,1	0,1	–0,3	–0,3	0,6	0,6
$f_{ctr\text{-stb}}$	0,9	–0,6	–0,4	–0,6	0,3	–0,4	0,2	1,0	1,0	0,3	0,3
$f_{bilge\text{-stb}}$	0,3	–0,5	–0,2	–1,0	1,0	–0,7	0,7	0,4	0,4	0,5	0,5
$f_{WL\text{-stb}}$	0,5	–0,2	0,1	–0,9	0,9	–0,6	0,6	0,6	0,6	1,0	1,0
$f_{ctr\text{-pt}}$	0,9	–0,6	–0,4	0,3	–0,6	0,2	–0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-pt}}$	0,3	–0,5	–0,2	1,0	–1,0	0,7	–0,7	0,4	0,4	0,5	0,5
$f_{WL\text{-pt}}$	0,5	–0,2	0,1	0,9	–0,9	0,6	–0,6	0,6	0,6	1,0	1,0

Table A1.31 Dynamic load cases for forward end region for light draught condition for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–0,9	–1,0	–1,0	–1,0	–1,0	–1,0	–1,0	0,1	0,1
f_{mh}	0,1	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,8	0,8
$f_{v\text{-mid}}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	0,1	0,1
$f_{v\text{-pt}}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	0,2	0,2
$f_{v\text{-stb}}$	1,0	–0,8	–0,8	–0,8	–1,0	–1,0	–0,5	–0,5	–0,1	–0,1
f_t	–0,1	0,0	0,0	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0
$f_{lng\text{-mid}}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-pt}}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-stb}}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{lng\text{-ctr}}$	–1,0	1,0	0,8	0,8	1,0	1,0	0,7	0,7	0,1	0,1
$f_{ctr\text{-stb}}$	–1,0	0,8	1,0	1,0	1,0	1,0	1,0	1,0	–0,2	0,1
$f_{bilge\text{-stb}}$	–0,7	0,6	0,7	0,7	1,0	0,9	0,8	0,7	–0,7	0,6
$f_{WL\text{-stb}}$	–0,4	0,4	0,6	0,6	0,9	0,8	1,0	0,8	–0,6	0,6
$f_{ctr\text{-pt}}$	–1,0	0,8	1,0	1,0	1,0	1,0	1,0	1,0	0,1	–0,2
$f_{bilge\text{-pt}}$	–0,7	0,6	0,7	0,7	0,9	1,0	0,7	0,8	0,6	–0,7
$f_{WL\text{-pt}}$	–0,4	0,4	0,6	0,6	0,8	0,9	0,8	1,0	0,6	–0,6

Table A1.32 Dynamic load cases for aft region for deep draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	–0,1	0,1	0,1	0,3	0,3	–0,5	–0,5
f_{mh}	0,4	–0,1	0,1	–0,4	0,4	–0,8	0,8
$f_{v\text{-}mid}$	1,0	–0,3	–0,3	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	1,0	–0,3	–0,3	1,0	1,0	0,1	0,5
$f_{v\text{-}stb}$	1,0	–0,3	–0,3	1,0	1,0	0,5	0,1
f_t	0,0	0,1	–0,1	0,3	–0,3	1,0	1,0
$f_{lng\text{-}mid}$	0,7	0,7	0,7	–0,4	–0,4	–0,2	–0,2
$f_{lng\text{-}pt}$	0,7	0,7	0,7	–0,4	–0,4	–0,1	–0,4
$f_{lng\text{-}stb}$	0,7	0,7	0,7	–0,4	–0,4	–0,4	–0,1
$f_{lng\text{-}ctr}$	0,7	0,7	0,7	–0,4	–0,4	–0,2	–0,2
$f_{ctr\text{-}stb}$	–1,0	0,4	0,4	–0,7	–0,7	0,6	0,6
$f_{bilge\text{-}stb}$	–1,0	0,5	0,5	–0,4	–0,7	0,1	1,0
$f_{WL\text{-}stb}$	–0,9	1,0	1,0	–0,2	–0,3	0,1	0,9
$f_{ctr\text{-}pt}$	–1,0	0,4	0,4	–0,7	–0,7	0,6	0,6
$f_{bilge\text{-}pt}$	–1,0	0,5	0,5	–0,7	–0,4	1,0	0,1
$f_{WL\text{-}pt}$	–0,9	1,0	1,0	–0,3	–0,2	0,9	0,1

Table A1.33 Dynamic load cases for central tank region for deep draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	1,0	–0,4	0,1	0,1	0,1	0,1	–0,6	–0,6	–0,1	–0,1
f_{mh}	0,0	–1,0	0,0	–1,0	1,0	–0,1	–0,1	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,7	1,0	–0,7	–0,5	–0,5	0,3	0,3	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}pt}$	0,7	1,0	–0,7	–0,5	–0,5	0,2	0,5	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}stb}$	0,7	1,0	–0,7	–0,5	–0,5	0,5	0,2	–0,2	–0,2	–0,1	–0,1
f_t	0,0	–0,2	0,0	0,2	0,2	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,3	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}pt}$	–0,3	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}stb}$	–0,3	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,3	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{ctr\text{-}stb}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}stb}$	0,8	0,9	0,3	–0,2	0,5	–0,7	0,3	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}stb}$	0,9	0,8	0,5	–0,1	0,4	–0,6	0,3	–0,7	–0,7	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}pt}$	0,8	0,9	0,3	0,5	–0,2	0,3	–0,7	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}pt}$	0,9	0,8	0,5	0,4	–0,1	0,3	–0,6	–0,7	–0,7	1,0	1,0

Table A1.34 Dynamic load cases for forward end region for deep draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,1	0,1	0,1	0,1	0,1	0,1	–0,2	–0,2	–0,4	–0,4
f_{mh}	–0,2	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,5	0,5
$f_{v\text{-}mid}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	0,9	0,9
$f_{v\text{-}pt}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	0,9	0,9
$f_{v\text{-}stb}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	0,9	0,9
f_t	0,3	0,0	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,5	–0,5
$f_{lng\text{-}pt}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,6	–0,6
$f_{lng\text{-}stb}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,5	–0,5
$f_{ctr\text{-}stb}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}stb}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,9	–0,6
$f_{WL\text{-}stb}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,9	–0,4
$f_{ctr\text{-}pt}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}pt}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,6	–0,9
$f_{WL\text{-}pt}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,4	–0,9

Table A1.35 Dynamic load cases for aft region for light draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,6	0,2	0,2	–0,5	–0,5	–0,8	–0,8
f_{mh}	0,0	–0,1	0,1	–0,4	0,4	–1,0	1,0
$f_{v\text{-}mid}$	0,3	–0,1	–0,1	1,0	1,0	0,3	0,3
$f_{v\text{-}pt}$	0,3	–0,1	–0,1	1,0	1,0	0,2	0,2
$f_{v\text{-}stb}$	0,3	–0,1	–0,1	1,0	1,0	0,5	0,5
f_t	0,0	0,1	–0,1	0,3	–0,3	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,4	–0,4
$f_{lng\text{-}pt}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,3	–0,5
$f_{lng\text{-}stb}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,5	–0,3
$f_{lng\text{-}ctr}$	0,1	–0,3	–0,3	–0,3	–0,3	–0,4	–0,4
$f_{ctr\text{-}stb}$	–1,0	0,2	0,2	–0,4	–0,4	–0,2	–0,1
$f_{bilge\text{-}stb}$	–1,0	0,2	0,2	–0,4	–0,5	–0,3	0,1
$f_{WL\text{-}stb}$	–1,0	1,0	1,0	–0,2	–0,3	–0,5	0,3
$f_{ctr\text{-}pt}$	–1,0	0,2	0,2	–0,4	–0,4	–0,1	–0,2
$f_{bilge\text{-}pt}$	–1,0	0,2	0,2	–0,5	–0,4	0,1	–0,3
$f_{WL\text{-}pt}$	–1,0	1,0	1,0	–0,3	–0,2	0,3	–0,5

Table A1.36 Dynamic load cases for central tank region for light draught condition for a weather vaning VLCC unit, Campos Basin

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	1,0	0,6	–0,3	–0,3	–0,1	–0,1	–0,6	–0,6	0,1	0,1
f_{mh}	0,0	–1,0	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,6	1,0	–0,8	–0,5	–0,5	0,3	0,3	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}pt}$	0,6	1,0	–0,8	–0,5	–0,5	0,2	0,5	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}stb}$	0,6	1,0	–0,8	–0,5	–0,5	0,5	0,2	–0,2	–0,2	–0,1	–0,1
f_t	0,0	–0,2	0,0	0,2	–0,2	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,4	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}pt}$	–0,4	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}stb}$	–0,4	–0,4	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,4	–0,2	1,0	–0,1	–0,1	–0,3	–0,3	0,1	0,1	–0,3	–0,3
$f_{ctr\text{-}stb}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}stb}$	0,5	0,9	0,3	–0,2	0,5	–0,7	0,3	–0,6	–0,6	0,4	0,4
$f_{WL\text{-}stb}$	0,5	0,8	0,5	–0,1	0,4	–0,6	0,3	–0,7	–0,7	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	1,0	0,2	0,3	0,3	–0,3	–0,3	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}pt}$	0,5	0,9	0,3	0,5	–0,2	0,3	–0,7	–0,6	–0,6	0,4	0,4
$f_{WL\text{-}pt}$	0,5	0,8	0,5	0,4	–0,1	0,3	–0,6	–0,7	–0,7	1,0	1,0

Table A1.37 Dynamic load cases for forward end region for light draught condition for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	1,0	–1,0	1,0	1,0	1,0	1,0	–0,3	–0,3	0,2	0,2
f_{mh}	–0,2	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	0,7	–0,7
$f_{v\text{-}mid}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	1,0	1,0
$f_{v\text{-}pt}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	1,0	1,0
$f_{v\text{-}stb}$	1,0	–0,6	0,9	0,9	0,9	0,9	–0,4	–0,4	1,0	1,0
f_t	0,3	0,0	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{lng\text{-}pt}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,6	–0,3
$f_{lng\text{-}stb}$	–0,2	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,3	–0,6
$f_{lng\text{-}ctr}$	–0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{ctr\text{-}stb}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}stb}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,8	0,8	–0,9	–0,6
$f_{WL\text{-}stb}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,9	–0,4
$f_{ctr\text{-}pt}$	–1,0	0,6	–1,0	–1,0	–1,0	–1,0	0,6	0,6	–0,7	–0,7
$f_{bilge\text{-}pt}$	–1,0	0,8	–1,0	–1,0	–1,0	–1,0	0,8	0,8	–0,6	–0,9
$f_{WL\text{-}pt}$	–0,8	0,5	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,4	–0,9

Table A1.38 Dynamic load cases for aft region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	1,0	0,1	0,1	0,2	0,2	0,1	0,1
f_{mh}	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,1	–0,1	–0,1	1,0	1,0	0,2	0,2
$f_{v\text{-}pt}$	0,1	–0,1	–0,1	1,0	1,0	0,4	0,1
$f_{v\text{-}stb}$	0,1	–0,1	–0,1	1,0	1,0	0,1	0,4
f_t	0,0	0,1	–0,1	0,4	–0,4	1,0	–1,0
$f_{lng\text{-}mid}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{lng\text{-}pt}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{lng\text{-}stb}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{lng\text{-}ctr}$	–0,2	–0,4	–0,4	–0,5	–0,5	–0,2	–0,2
$f_{ctr\text{-}stb}$	–1,0	0,3	0,3	–0,9	–0,9	0,2	–0,4
$f_{bilge\text{-}stb}$	–0,7	0,5	0,5	–0,6	–0,5	0,4	–0,7
$f_{WL\text{-}stb}$	–0,6	1,0	1,0	–0,4	–0,2	0,5	–0,7
$f_{ctr\text{-}pt}$	–1,0	0,3	0,3	–0,9	–0,9	–0,4	0,2
$f_{bilge\text{-}pt}$	–0,7	0,5	0,5	–0,5	–0,6	–0,7	0,4
$f_{WL\text{-}pt}$	–0,6	1,0	1,0	–0,2	–0,4	–0,7	0,5

Table A1.39 Dynamic load cases for central tank region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,2	–0,4	0,1	0,1	0,1	0,1	–1,0	–1,0	–0,1	–0,1
f_{mh}	0,0	–0,1	0,0	–1,0	1,0	–0,5	0,5	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,2	1,0	–0,6	–0,6	–0,6	0,4	0,4	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}pt}$	0,2	1,0	–0,6	–0,6	–0,6	0,6	0,2	–0,2	–0,2	–0,1	–0,1
$f_{v\text{-}stb}$	0,2	1,0	–0,6	–0,6	–0,6	0,2	0,6	–0,2	–0,2	–0,1	–0,1
f_t	0,0	0,5	0,0	0,1	–0,1	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{lng\text{-}pt}$	–0,2	–0,5	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{lng\text{-}stb}$	–0,2	–0,5	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{lng\text{-}ctr}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,2	0,2	–0,3	–0,3
$f_{ctr\text{-}stb}$	1,0	–0,9	0,1	0,4	0,3	–0,2	–0,4	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}stb}$	0,5	–0,9	0,2	0,5	0,1	0,2	–0,7	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}stb}$	0,7	–0,6	0,5	0,6	0,2	0,3	–0,8	–0,6	–0,6	1,0	1,0
$f_{ctr\text{-}pt}$	1,0	–0,9	0,1	0,3	0,4	–0,4	–0,2	–1,0	–1,0	0,1	0,1
$f_{bilge\text{-}pt}$	0,5	–0,9	0,2	0,1	0,5	–0,7	0,2	–0,5	–0,5	0,4	0,4
$f_{WL\text{-}pt}$	0,7	–0,6	0,5	0,2	0,6	–0,8	0,3	–0,6	–0,6	1,0	1,0

Table A1.40 Dynamic load cases for forward end region for deep draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,8	0,1	0,1	0,1	0,1	0,1	–0,2	–0,2	–0,1	–0,1
f_{mh}	0,3	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–0,4	0,4
$f_{v\text{-}mid}$	1,0	–0,5	–0,6	–0,6	0,7	0,7	–0,6	–0,6	0,5	0,5
$f_{v\text{-}pt}$	1,0	–0,5	–0,6	–0,6	0,7	0,7	–0,6	–0,6	0,5	0,5
$f_{v\text{-}stb}$	1,0	–0,5	–0,6	–0,6	0,7	0,7	–0,6	–0,6	0,5	0,5
f_t	–0,4	0,0	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{lng\text{-}pt}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,3	–0,5
$f_{lng\text{-}stb}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,5	–0,3
$f_{lng\text{-}ctr}$	0,1	1,0	–0,6	–0,6	–0,5	–0,5	0,3	0,3	–0,4	–0,4
$f_{ctr\text{-}stb}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,5	–0,5
$f_{bilge\text{-}stb}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,1	–0,8
$f_{WL\text{-}stb}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,1	–0,9
$f_{ctr\text{-}pt}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,5	–0,5
$f_{bilge\text{-}pt}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,8	–0,1
$f_{WL\text{-}pt}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,9	–0,1

Table A1.41 Dynamic load cases for aft region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	P_{ctr}	P_{WL}		a_v		a_t	
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,6	–0,5	–0,5	–0,6	–0,6	0,3	0,3
f_{mh}	0,0	–0,1	0,1	–0,4	0,4	–1,0	1,0
$f_{v\text{-}mid}$	0,4	–0,2	–0,2	1,0	1,0	–0,1	–0,1
$f_{v\text{-}pt}$	0,4	–0,2	–0,2	1,0	1,0	–0,4	–0,3
$f_{v\text{-}stb}$	0,4	–0,2	–0,2	1,0	1,0	–0,3	–0,4
f_t	0,0	0,1	–0,1	0,4	–0,4	1,0	–1,0
$f_{lng\text{-}mid}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,5	0,5
$f_{lng\text{-}pt}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,4	0,6
$f_{lng\text{-}stb}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,6	0,4
$f_{lng\text{-}ctr}$	–0,3	–0,1	–0,1	–0,5	–0,5	0,5	0,5
$f_{ctr\text{-}stb}$	–1,0	0,9	0,9	–0,5	–0,5	0,2	0,2
$f_{bilge\text{-}stb}$	–1,0	0,9	0,9	–0,7	–0,7	0,6	–0,4
$f_{WL\text{-}stb}$	–0,7	1,0	1,0	–0,3	–0,3	0,8	–0,8
$f_{ctr\text{-}pt}$	–1,0	0,9	0,9	–0,5	–0,5	0,2	0,2
$f_{bilge\text{-}pt}$	–1,0	0,9	0,9	–0,7	–0,7	–0,4	0,6
$f_{WL\text{-}pt}$	–0,7	1,0	1,0	–0,3	–0,3	–0,8	0,8

Table A1.42 Dynamic load cases for central tank region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$		a_t		P_{ctr}		P_{WL}	
Dynamic load case	1(Hog)	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,2	0,1	–0,6	–0,6	–0,1	–0,1	–0,9	–0,9	0,9	0,9
f_{mh}	0,0	–0,2	0,0	–1,0	1,0	–0,8	0,8	–0,1	0,1	–0,1	0,1
$f_{v\text{-}mid}$	0,3	1,0	0,2	–0,7	–0,7	0,3	0,3	0,1	0,1	–0,2	–0,2
$f_{v\text{-}pt}$	0,3	1,0	0,2	–0,7	–0,7	0,1	0,1	0,1	0,1	–0,2	–0,2
$f_{v\text{-}stb}$	0,3	1,0	0,2	–0,7	–0,7	0,5	0,5	0,1	0,1	–0,2	–0,2
f_t	0,0	0,5	0,0	0,1	–0,1	1,0	–1,0	0,1	–0,1	0,1	–0,1
$f_{lng\text{-}mid}$	–0,2	–0,3	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}pt}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}stb}$	–0,2	–0,4	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}ctr}$	–0,2	–0,3	1,0	0,1	0,1	–0,2	–0,2	0,1	0,1	–0,1	–0,1
$f_{ctr\text{-}stb}$	0,8	–0,8	–0,1	0,3	0,2	–0,1	–0,2	–1,0	–1,0	1,0	1,0
$f_{bilge\text{-}stb}$	0,4	–0,9	–0,1	0,6	0,1	0,4	–0,8	–0,7	–0,7	0,7	0,7
$f_{WL\text{-}stb}$	0,5	–0,5	–0,2	0,7	0,1	0,4	–0,7	–0,7	–0,7	0,9	0,9
$f_{ctr\text{-}pt}$	0,8	–0,8	–0,1	0,2	0,3	–0,2	–0,1	–1,0	–1,0	1,0	1,0
$f_{bilge\text{-}pt}$	0,4	–0,9	–0,1	0,1	0,6	–0,8	0,4	–0,7	–0,7	0,7	0,7
$f_{WL\text{-}pt}$	0,5	–0,5	–0,2	0,1	0,7	–0,7	0,4	–0,7	–0,7	0,9	0,9

Table A1.43 Dynamic load cases for forward end region for light draught condition for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	a_v	a_{lng}	P_{ctr}		P_{bilge}		P_{WL}		a_t	
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,2	–1,0	0,9	0,9	0,9	0,9	–0,7	–0,7	0,1	0,1
f_{mh}	–0,5	0,0	–0,1	0,1	–0,1	0,1	–0,1	0,1	–1,0	1,0
$f_{v\text{-}mid}$	1,0	–0,5	0,8	0,8	0,8	0,8	–0,6	–0,6	0,5	0,5
$f_{v\text{-}pt}$	1,0	–0,5	0,8	0,8	0,8	0,8	–0,6	–0,6	0,5	0,5
$f_{v\text{-}stb}$	1,0	–0,5	0,8	0,8	0,8	0,8	–0,6	–0,6	0,5	0,5
f_t	–0,4	0,0	0,1	–0,1	0,1	–0,1	0,1	–0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,4	–0,4
$f_{lng\text{-}pt}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,3	–0,5
$f_{lng\text{-}stb}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,5	–0,3
$f_{lng\text{-}ctr}$	0,1	1,0	–0,5	–0,5	–0,5	–0,5	0,4	0,4	–0,4	–0,4
$f_{ctr\text{-}stb}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,4	–0,5
$f_{bilge\text{-}stb}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,1	–0,8
$f_{WL\text{-}stb}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,1	–0,9
$f_{ctr\text{-}pt}$	–0,7	0,7	–1,0	–1,0	–1,0	–1,0	0,9	0,9	–0,5	–0,4
$f_{bilge\text{-}pt}$	–0,8	0,8	–1,0	–1,0	–1,0	–1,0	1,0	1,0	–0,8	–0,1
$f_{WL\text{-}pt}$	–0,6	0,4	–0,8	–0,8	–0,8	–0,8	1,0	1,0	–0,9	–0,1

Table A1.44 Dynamic load cases for aft end region for deep draught condition for a spread moored VLCC unit Nigeria

Max. response	P_{ctr}	P_{wl}	P_{wl}	a_v	a_v	a_t	a_t
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	0,8	0,1	0,1	0,1	0,1	0,1	–0,1
f_{mh}	0,1	–0,4	–0,4	0,0	0,0	0,3	–0,3
$f_{v\text{-}mid}$	0,2	0,0	0,0	1,0	1,0	0,1	–0,1
$f_{v\text{-}pt}$	0,2	0,0	0,0	1,0	1,0	0,1	–0,1
$f_{v\text{-}stb}$	0,2	0,0	0,0	1,0	1,0	0,1	–0,1
f_t	–0,1	0,0	0,0	0,0	0,0	1,0	–1,0
$f_{lng\text{-}mid}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{lng\text{-}pt}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{lng\text{-}stb}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{lng\text{-}ctr}$	0,7	0,4	0,4	0,0	0,0	0,0	0,0
$f_{ctr\text{-}stb}$	1,0	0,3	0,3	0,2	0,2	0,1	–0,1
$f_{bilge\text{-}stb}$	0,9	0,5	0,5	0,1	0,1	–0,3	0,3
$f_{wl\text{-}stb}$	0,7	1,0	1,0	0,1	0,1	–0,3	0,3
$f_{ctr\text{-}pt}$	1,0	0,3	0,3	0,2	0,2	0,1	–0,1
$f_{bilge\text{-}pt}$	0,9	0,5	0,5	0,1	0,1	–0,3	0,3
$f_{wl\text{-}pt}$	0,7	1,0	1,0	0,1	0,1	–0,3	0,3

Table A1.45 Dynamic load cases for central tank region for deep draught condition for a spread moored VLCC unit Nigeria

Max. response	M_{wv}	a_v	a_{lng}	M_{wvh}	M_{wvh}	a_t	a_t	P_{ctr}	P_{ctr}	P_{wl}	P_{wl}
Dynamic load case	1	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,7	–0,4	0,5	–0,5	0,2	–0,2	–0,6	–0,6	–0,5	–0,5
f_{mh}	0,0	–0,6	0,5	–1,0	1,0	–0,1	0,1	0,0	0,0	–0,1	–0,1
$f_{v\text{-}mid}$	0,8	1,0	–0,6	0,6	–0,6	0,2	–0,2	0,0	0,0	0,1	0,1
$f_{v\text{-}pt}$	0,8	1,0	–0,6	0,6	–0,6	0,2	–0,2	0,0	0,0	0,1	0,1
$f_{v\text{-}stb}$	0,7	1,0	–0,6	0,6	–0,6	0,3	–0,3	0,0	0,0	0,1	0,1
f_t	0,0	0,1	0,0	0,2	–0,2	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}pt}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}stb}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{lng\text{-}ctr}$	0,0	–1,0	1,0	–0,6	0,6	–0,1	0,1	0,1	0,1	–0,1	–0,1
$f_{ctr\text{-}stb}$	–0,9	–0,2	0,1	–0,3	0,3	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}stb}$	–0,8	0,4	–0,2	0,3	–0,3	–0,8	0,8	1,0	1,0	1,0	1,0
$f_{wl\text{-}stb}$	–0,7	0,2	–0,1	0,3	–0,3	–0,4	0,4	0,9	0,9	1,0	1,0
$f_{ctr\text{-}pt}$	–0,9	–0,2	0,1	–0,3	0,3	0,0	0,0	1,0	1,0	1,0	1,0
$f_{bilge\text{-}pt}$	–0,8	0,4	–0,2	0,3	–0,3	–0,8	0,8	1,0	1,0	1,0	1,0
$f_{wl\text{-}pt}$	–0,7	0,2	–0,1	0,3	–0,3	–0,4	0,4	0,9	0,9	1,0	1,0

Table A1.46 Dynamic load cases for forward end region for deep draught condition for a spread moored VLCC unit, Nigeria

Max. response	a_v	a_{lng}	P_{ctr}	P_{ctr}	P_{bilge}	P_{bilge}	P_{wl}	P_{wl}	a_t	a_t
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	–0,5	0,5	–0,4	–0,4	–0,4	–0,4	–0,3	–0,3	–0,1	0,1
f_{mh}	–0,2	0,2	–0,1	–0,1	–0,1	–0,1	0,1	0,1	0,9	–0,9
$f_{v\text{-}mid}$	1,0	–1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,2	–0,2
$f_{v\text{-}pt}$	1,0	–1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	–0,1
$f_{v\text{-}stb}$	1,0	–1,0	1,0	1,0	1,0	1,0	0,7	0,7	0,1	–0,1
f_t	0,1	–0,1	0,1	0,1	0,1	0,1	0,3	0,3	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,0	0,0
$f_{lng\text{-}pt}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	–0,1	0,1
$f_{lng\text{-}stb}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	–0,1	0,1
$f_{lng\text{-}ctr}$	–1,0	1,0	–1,0	–1,0	–1,0	–1,0	–0,7	–0,7	0,0	0,0
$f_{ctr\text{-}stb}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,2	–0,2
$f_{bilge\text{-}stb}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,9	0,9	0,5	–0,5
$f_{wl\text{-}stb}$	0,6	–0,6	0,8	0,8	0,8	0,8	1,0	1,0	0,2	–0,2
$f_{ctr\text{-}pt}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,7	0,7	0,2	–0,2
$f_{bilge\text{-}pt}$	0,9	–0,9	1,0	1,0	1,0	1,0	0,9	0,9	0,5	–0,5
$f_{wl\text{-}pt}$	0,6	–0,6	0,8	0,8	0,8	0,8	1,0	1,0	0,2	–0,2

Table A1.47 Dynamic load cases for aft end region for light draught condition for a spread moored VLCC unit, Nigeria

Max. response	P_{ctr}	P_{wl}	P_{wl}	a_v	a_v	a_t	a_t
Dynamic load case	1	2S	2P	3S	3P	4S	4P
f_{mv}	1,0	0,9	0,9	0,3	0,3	0,4	–0.4
f_{mh}	–0,2	–0,5	–0,5	0,2	0,2	0,6	–0,6
$f_{v\text{-}mid}$	0,5	0,0	0,0	1,0	1,0	0,5	–0.5
$f_{v\text{-}pt}$	0,5	0,0	0,0	1,0	1,0	0,5	–0,5
$f_{v\text{-}stb}$	0,5	0,0	0,0	1,0	1,0	0,5	–0,5
f_t	–0,1	–0,1	–0,1	0,1	0,1	1,0	–1,0
$f_{lng\text{-}mid}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{lng\text{-}pt}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{lng\text{-}stb}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{lng\text{-}ctr}$	0,2	0,1	0,1	1,0	1,0	0,1	–0,1
$f_{ctr\text{-}stb}$	1,0	1,0	1,0	0,4	0,4	0,4	–0,4
$f_{bilge\text{-}stb}$	0,7	0,9	0,9	0,3	0,3	–0,7	0,7
$f_{wl\text{-}stb}$	0,6	1,0	1,0	0,1	0,1	–0,7	0,7
$f_{ctr\text{-}pt}$	1,0	1,0	1,0	0,4	0,4	0,4	–0,4
$f_{bilge\text{-}pt}$	0,7	0,9	0,9	0,3	0,3	–0,7	0,7
$f_{wl\text{-}pt}$	0,6	1,0	1,0	0,1	0,1	–0,7	0,7

Table A1.48 **Dynamic load cases for central tank region for light draught condition for a spread moored VLCC unit, Nigeria**

Max. response	M_{wv}	a_v	a_{lng}	$M_{wv\text{-}h}$	$M_{wv\text{-}h}$	a_t	a_t	P_{ctr}	P_{ctr}	P_{wl}	P_{wl}
Dynamic load case	1	2	3	4S	4P	5S	5P	6S	6P	7S	7P
f_{mv}	1,0	0,1	–0,3	0,5	–0,5	0,4	–0,4	–0,9	–0,9	–0,2	–0,2
f_{mh}	0,0	–0,2	0,4	–1,0	1,0	–0,5	0,5	0,1	0,1	0,3	0,3
$f_{v\text{-}mid}$	0,6	1,0	–0,5	0,5	–0,5	0,5	–0,5	–0,2	–0,2	0,0	0,0
$f_{v\text{-}pt}$	0,4	1,0	–0,3	0,4	–0,4	0,9	–0,9	–0,2	–0,2	0,0	0,0
$f_{v\text{-}stb}$	0,4	1,0	–0,3	0,4	–0,4	0,9	–0,9	–0,2	–0,2	0,0	0,0
f_t	0,0	0,0	0,0	0,1	–0,1	1,0	–1,0	0,0	0,0	0,0	0,0
$f_{lng\text{-}mid}$	–0,3	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,4	0,4	–0,1	–0,1
$f_{lng\text{-}pt}$	–0,2	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,3	0,3	–0,1	–0,1
$f_{lng\text{-}stb}$	–0,2	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,3	0,3	–0,1	–0,1
$f_{lng\text{-}ctr}$	–0,3	–0,9	1,0	–0,8	0,8	0,1	–0,1	0,4	0,4	–0,1	–0,1
$f_{ctr\text{-}stb}$	–1,0	0,3	0,3	–0,5	0,5	–0,4	0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}stb}$	–0,7	0,4	0,4	–0,7	0,7	0,6	–0,6	0,8	0,8	0,7	0,7
$f_{wl\text{-}stb}$	–0,5	0,0	0,4	–0,8	0,8	0,4	–0,4	0,6	0,6	1,0	1,0
$f_{ctr\text{-}pt}$	–1,0	0,3	0,3	–0,5	0,5	–0,4	0,4	1,0	1,0	0,3	0,3
$f_{bilge\text{-}pt}$	–0,7	0,4	0,4	–0,7	0,7	0,6	–0,6	0,8	0,8	0,7	0,7
$f_{wl\text{-}pt}$	–0,5	0,0	0,4	–0,8	0,8	0,4	–0,4	0,6	0,6	1,0	1,0

Table A1.49 **Dynamic load cases for forward end region for light draught condition for a spread moored VLCC unit, Nigeria**

Max. response	a_v	a_{lng}	P_{ctr}	P_{ctr}	P_{bilge}	P_{bilge}	P_{wl}	P_{wl}	a_t	a_t
Dynamic load case	1	2	3S	3P	4S	4P	5S	5P	6S	6P
f_{mv}	0,6	–0,5	0,9	0,9	0,9	0,9	–0,5	–0,5	0,4	–0,4
f_{mh}	–0,1	0,1	0,1	0,1	0,8	0,8	–1,0	–1,0	0,9	–0.9
$f_{v\text{-}mid}$	1,0	–0,8	0,8	0,8	0,3	0,3	0,0	0,0	0,1	–0,1
$f_{v\text{-}pt}$	1,0	–0,8	0,7	0,7	0,1	0,1	0,4	0,4	–0,2	0,2
$f_{v\text{-}stb}$	1,0	–0,8	0,7	0,7	0,1	0,1	0,4	0,4	–0,2	0,2
f_t	0,0	0,0	0,0	0,0	0,9	0,9	–1,0	–1,0	1,0	–1,0
$f_{lng\text{-}mid}$	–1,0	1,0	–0,7	–0,7	–0,1	–0,1	–0,1	–0,1	0,1	–0,1
$f_{lng\text{-}pt}$	–1,0	1,0	–0,7	–0,7	–0,2	–0,2	0,0	0,0	0,0	0,0
$f_{lng\text{-}stb}$	–1,0	1,0	–0,7	–0,7	–0,2	–0,2	0,0	0,0	0,0	0,0
$f_{lng\text{-}ctr}$	–1,0	1,0	–0,7	–0,7	–0,1	–0,1	–0,1	–0,1	0,1	–0,1
$f_{ctr\text{-}stb}$	0,8	–0,7	1,0	1,0	0,7	0,7	–0,2	–0,2	0,2	–0,2
$f_{bilge\text{-}stb}$	0,6	–0,5	0,7	0,7	1,0	1,0	–1,0	–1,0	0,8	–0,8
$f_{wl\text{-}stb}$	0,4	–0,3	0,6	0,6	–0,3	–0,3	1,0	1,0	–0,7	0,7
$f_{ctr\text{-}pt}$	0,8	–0,7	1,0	1,0	0,7	0,7	–0,2	–0,2	0,2	–0,2
$f_{bilge\text{-}pt}$	0,6	–0,5	0,7	0,7	1,0	1,0	–1,0	–1,0	0,8	–0,8
$f_{wl\text{-}pt}$	0,4	–0,3	0,6	0,6	–0,3	–0,3	1,0	1,0	–0,7	0,7

Table A1.50 Dynamic load cases for strength assessment (by FEM), unrestricted worldwide transit

Wave direction	Head sea				Beam sea		Oblique sea	
Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		$M_{wv\text{-}h}$	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–1,0	1,0	0,0	0,0	0,4	0,4
f_{qv}	1,0	–1,0	1,0	–1,0	0,0	0,0	0,0	0,0
f_{mh}	0,0	0,0	0,0	0,0	0,0	0,0	1,0	–1,0
f_v	0,5	–0,5	0,3	–0,3	1,0	1,0	–0,1	–0,1
f_t	0,0	0,0	0,0	0,0	–0,6	0,6	0,0	0,0
f_{lng}	–0,6	0,6	–0,6	0,6	–0,5	–0,5	0,5	0,5
$f_{WL\text{-}pt}$	–0,3	0,3	0,1	–0,1	1,0	0,4	0,6	0,0
$f_{bilge\text{-}pt}$	–0,3	0,3	0,1	–0,1	1,0	0,4	0,4	0,0
$f_{ctr\text{-}pt}$	–0,7	0,7	0,3	–0,3	0,9	0,9	0,5	0,5
$f_{WL\text{-}stb}$	–0,3	0,3	0,1	–0,1	0,4	1,0	0,0	0,6
$f_{bilge\text{-}stb}$	–0,3	0,3	0,1	–0,1	0,4	1,0	0,0	0,4
$f_{ctr\text{-}stb}$	–0,7	0,7	0,3	–0,3	0,9	0,9	0,5	0,5

Table A1.51 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, west of Shetland Is.

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		$M_{wv\text{-}h}$	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,9	0,9	0,4	0,4	0,2	0,2
f_{qv}	1,0	–1,0	1,0	–1,0	–0,2	–0,2	–0,2	–0,2
f_{mh}	0,1	–0,1	0,0	0,0	–0,2	0,2	–1,0	1,0
f_v	–0,6	0,6	–0,2	0,2	1,0	1,0	0,0	0,0
f_t	0,0	0,0	0,0	0,0	0,2	–0,2	0,0	0,0
f_{lng}	0,6	–0,6	0,1	–0,1	–0,1	–0,1	0,6	0,6
$f_{WL\text{-}pt}$	–0,8	0,8	–0,8	0,8	–0,2	–0,7	–0,1	0,3
$f_{bilge\text{-}pt}$	–0,5	0,5	–0,5	0,5	–0,5	–1,0	–0,1	0,4
$f_{ctr\text{-}pt}$	–1,0	1,0	–1,0	1,0	–0,9	–1,0	0,2	0,2
$f_{WL\text{-}stb}$	–0,8	0,8	–0,8	0,8	–0,7	–0,2	0,3	–0,1
$f_{bilge\text{-}stb}$	–0,5	0,5	–0,5	0,5	–1,0	–0,5	0,4	–0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	–1,0	1,0	–1,0	–0,9	0,2	0,2

Table A1.52 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, North Sea

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,8	0,8	0,3	0,3	–0,3	–0,3
f_{qv}	0,8	–0,8	1,0	–1,0	–0,2	0,2	0,1	0,1
f_{mh}	0,3	–0,3	0,1	–0,1	–0,1	0,1	–1,0	1,0
f_v	–0,7	0,7	–0,1	0,1	1,0	1,0	–0,3	–0,3
f_t	–0,1	0,1	0,0	0,0	0,3	–0,3	0,1	–0,1
f_{lng}	0,9	–0,9	0,2	–0,2	–0,1	–0,1	0,4	0,4
f_{WL-pt}	–0,8	0,8	–1,0	1,0	–0,2	–0,5	0,1	–0,2
$f_{bilge-pt}$	–0,6	0,6	–0,9	0,9	–0,6	–0,9	0,2	0,3
f_{ctr-pt}	–1,0	1,0	–1,0	1,0	–0,9	–0,9	–0,1	–0,2
f_{WL-stb}	–0,8	0,8	–1,0	1,0	–0,5	–0,2	–0,2	0,1
$f_{bilge-stb}$	–0,6	0,6	–0,9	0,9	–0,9	–0,6	–0,3	0,2
$f_{ctr-stb}$	–1,0	1,0	–1,0	1,0	–0,9	–0,9	–0,2	–0,1

Table A1.53 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, Brazil Campos Basin

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		M_{wv-h}	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,8	0,8	0,4	0,4	–0,2	–0,2
f_{qv}	0,9	–0,9	1,0	–1,0	–0,2	–0,2	0,2	0,2
f_{mh}	0,4	–0,4	–0,1	0,1	–0,2	0,2	–1,0	1,0
f_v	–0,5	0,5	–0,2	0,2	1,0	1,0	–0,1	–0,1
f_t	–0,1	0,1	0,0	0,0	0,2	–0,2	0,1	–0,1
f_{lng}	1,0	–1,0	0,4	–0,4	–0,1	–0,1	0,4	0,4
f_{WL-pt}	–0,6	0,6	–0,8	0,8	–0,2	–0,5	0,1	–0,2
$f_{bilge-pt}$	–0,3	0,3	–0,4	0,4	–0,5	–0,6	0,1	–0,2
f_{ctr-pt}	–0,7	0,7	–0,8	0,8	–1,0	–1,0	–0,2	–0,2
f_{WL-stb}	–0,6	0,6	–0,8	0,8	–0,5	–0,2	–0,2	0,1
$f_{bilge-stb}$	–0,3	0,3	–0,4	0,4	–0,6	–0,5	–0,2	0,1
$f_{ctr-stb}$	–0,7	0,7	–0,8	0,8	–1,0	–1,0	–0,2	–0,2

Table A1.54 Dynamic load cases for strength assessment by FEM for a weather vaning aframax unit, Western Australia (non-cyclonic)

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		$M_{wv\text{-}h}$	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–1,0	1,0	0,8	0,8	0,4	0,4
f_{qv}	1,0	–1,0	1,0	–1,0	–0,6	–0,6	–0,2	–0,2
f_{mh}	0,1	–0,1	–0,1	0,1	–0,1	0,1	–1,0	1,0
f_v	–0,4	0,4	–0,4	0,4	1,0	1,0	0,2	0,2
f_t	–0,1	0,1	–0,1	0,1	0,1	–0,1	0,1	–0,1
f_{lng}	0,3	–0,3	0,1	–0,1	–0,4	–0,4	–0,6	–0,6
$f_{WL\text{-}pt}$	–0,4	0,4	–0,5	0,5	–0,1	–0,2	–0,1	0,3
$f_{bilge\text{-}pt}$	–0,2	0,2	–0,2	0,2	–0,5	–0,5	–0,2	0,3
$f_{ctr\text{-}pt}$	–0,4	0,4	–0,4	0,4	–0,8	–0,8	0,2	0,2
$f_{WL\text{-}stb}$	–0,4	0,4	–0,5	0,5	–0,2	–0,1	0,3	–0,1
$f_{bilge\text{-}stb}$	–0,2	0,2	–0,2	0,2	–0,5	–0,5	0,3	–0,2
$f_{ctr\text{-}stb}$	–0,4	0,4	–0,4	0,4	–0,8	–0,8	0,2	0,2

Table A1.55 Dynamic load cases for strength assessment by FEM for a weather vaning VLCC unit, Brazil Campos Basin

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		$M_{wv\text{-}h}$	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,4	0,4	1,0	1,0	0,3	0,3
f_{qv}	0,7	–0,7	1,0	–1,0	1,0	1,0	–1,0	–1,0
f_{mh}	0,0	0,0	0,0	0,0	–1,0	1,0	–1,0	1,0
f_v	0,7	0,7	–0,5	0,5	1,0	1,0	–0,5	–0,5
f_t	0,0	0,0	0,0	0,0	0,2	–0,2	0,2	–0,2
f_{lng}	0,3	–0,3	0,7	–0,7	–0,4	–0,4	–0,1	–0,1
$f_{WL\text{-}pt}$	–0,8	0,8	–0,5	0,5	0,2	0,8	0,4	–0,1
$f_{bilge\text{-}pt}$	–0,8	0,8	–0,3	0,3	0,3	0,9	0,6	–0,3
$f_{ctr\text{-}pt}$	–1,0	1,0	–0,2	0,2	0,7	1,0	0,2	0,2
$f_{WL\text{-}stb}$	–0,8	0,8	–0,5	0,5	0,8	0,2	–0,1	0,4
$f_{bilge\text{-}stb}$	–0,8	0,8	–0,3	0,3	0,9	0,3	–0,3	0,6
$f_{ctr\text{-}stb}$	–1,0	1,0	–0,2	0,2	1,0	0,7	0,2	0,2

Table A1.56 Dynamic load cases for strength assessment by FEM for a weather vaning VLCC unit, Western Australia (non-cyclonic)

Max. response	M_{wv} (Sagging)	M_{wv} (Hogging)	Q_{wv} (Positive)	Q_{wv} (Negative)	a_v		$M_{wv\text{-}h}$	
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	–0,5	0,5	0,2	0,2	0,6	0,6
f_{qv}	0,5	–0,5	1,0	–1,0	–0,2	–0,2	1,0	1,0
f_{mh}	0,0	0,0	0,0	0,0	–0,2	0,2	–1,0	1,0
f_v	–0,3	0,3	–0,5	0,5	1,0	1,0	–0,6	–0,6
f_t	0,0	0,0	0,0	0,0	0,5	–0,5	0,1	–0,1
f_{lng}	0,2	–0,2	0,6	–0,6	–0,5	–0,5	0,1	0,1
$f_{WL\text{-}pt}$	–0,7	0,7	–0,4	0,4	–0,2	–0,5	0,2	0,6
$f_{bilge\text{-}pt}$	–0,5	0,5	–0,2	0,2	–0,6	–1,0	0,1	0,6
$f_{ctr\text{-}pt}$	–1,0	1,0	–0,3	0,3	–0,9	–0,9	0,4	0,4
$f_{WL\text{-}stb}$	–0,7	0,7	–0,4	0,4	–0,5	–0,2	0,6	0,2
$f_{bilge\text{-}stb}$	–0,5	0,5	–0,2	0,2	–1,0	–0,6	0,6	0,1
$f_{ctr\text{-}stb}$	–1,0	1,0	–0,3	0,3	–0,9	–0,9	0,4	0,4

Table A1.57 Dynamic load cases for strength assessment by FEM for a spread moored VLCC unit, Nigeria

Max. response	M_{wv}	M_{wv}	Q_{wv}	Q_{wv}	a_v	a_v	M_{wvh}	M_{wvh}
Dynamic load case	1	2	3	4	5S	5P	6S	6P
f_{mv}	–1,0	1,0	0,4	–0,4	0,7	0,7	0,5	–0,5
f_{qv}	0,0	0,0	1,0	–1,0	1,0	1,0	0,7	–0,7
f_{mh}	0,0	0,0	–0,4	0,4	–0,6	–0,6	–1,0	1,0
f_v	–0,8	0,8	0,6	–0,6	1,0	1,0	0,6	–0,6
f_t	0,0	0,0	0,0	0,0	0,1	0,1	0,2	–0,2
f_{lng}	0,0	0,0	–1,0	1,0	–1,0	–1,0	–0,6	0,6
$f_{wl\text{-}pt}$	0,7	–0,7	0,2	–0,2	0,2	0,2	0,3	–0,3
$f_{bilge\text{-}pt}$	0,8	–0,8	0,3	–0,3	0,4	0,4	0,3	–0,3
$f_{ctr\text{-}pt}$	0,9	–0,9	–0,1	0,1	–0,2	–0,2	–0,3	0,3
$f_{wl\text{-}stb}$	0,7	–0,7	0,2	–0,2	0,2	0,2	0,3	–0,3
$f_{bilge\text{-}stb}$	0,8	–0,8	0,3	–0,3	0,4	0,4	0,3	–0,3
$f_{ctr\text{-}stb}$	0,9	–0,9	–0,1	0,1	–0,2	–0,2	–0,3	0,3

Rules and Regulations for the Classification of Offshore Units

Part 11
Production, Storage and Offloading of Liquefied Gases in Bulk

July 2014

Lloyd's Register

Chapter Contents

Part 11

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Guide to the reader

This Part incorporates risk mitigation measures taken and adapted from the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code). However, if alternative measures have been defined for an installation, in accordance with the operating philosophy or safety philosophy of the installation, these alternative measures may be considered.

All paragraphs, Figures and Tables taken from the revised IGC Code, including any IGC Code amendments up to the date of publication of these Rules, are prefixed with the corresponding IGC Code paragraph numbers, e.g., 2.1.1.

Where IGC Code content has been modified in order for application to ship units engaged in the production, storage and offloading of liquefied gases at a fixed location, the revised text is shown underlined. Where paragraphs, Figures and Tables have been taken from the IGC Code and renumbered, the modified number(s) are shown underlined, e.g., 1.2.3.

In general, for the purposes of classification, the words 'should be' in IGC Code text are to be read as 'is to be' or 'are to be', as appropriate.

IGC Code content which is not considered applicable and/or beneficial to the objective of these Rules has not been included, to prevent misapplication.

Paragraphs, Figures and Tables which do not appear in the IGC Code are prefixed by 'LR', e.g., LR 1.1.1.

1.1 Application

LR 1.1.1 The purpose of this Part is to provide requirements to ensure the safe operation and inspection/maintenance of ship units engaged in the production, storage and offloading of liquefied gases at a fixed location. Ship units engaged solely in the storage and offloading of liquefied gases at a fixed location are also to comply with this Part, as applicable.

LR 1.1.2 The requirements in this Part are applicable to hull construction in steel.

LR 1.1.3 This Part considers only the design requirements for the production, storage and offloading of liquefied gases of the unit. Ship units are to comply with Part 10 and other relevant Parts in addition to the requirements of this Part.

LR 1.1.4 The requirements prescribed in this Part are applicable only to liquefied hydrocarbon gases (liquefied natural gas and liquefied petroleum gas), nitrogen and carbon dioxide. The products for which this Part is applicable are listed in Chapter 19. Requirements are not prescribed for products that are considered toxic by the IGC Code. Proposals to produce, store and offload products not listed in Chapter 19 are to be individually considered and the arrangements are to be acceptable to the Administration.

LR 1.1.5 Integral tanks, that form a structural part of the hull, for the storage of gas condensate are to comply with Part 10, *see* Pt 10, Ch 1,1.1.12.

LR 1.1.6 Integral tanks, that form a structural part of the hull, for the bulk storage of liquid chemicals necessary for treatment of the feed gas, e.g., monoethylene glycol (MEG) and amine solvents, are to comply with Part 10, *see* Pt 10, Ch 1,1.1.13. The structural design of independent tanks for the bulk storage of liquid chemicals is to comply with the requirements of Chapter 4 and Pt 10, Ch 1,1.1.13(b) and (c).

1.1.1 Flammable liquids having a flashpoint of 60°C (closed-cup test) or less and the flammable products listed in Chapter 19 shall not be carried in tanks located within the protective zones described in 2.4.1, within the longitudinal extent of the hold spaces for those tanks.

1.1.2 Where a risk assessment or study of similar intent is utilised within this Part, the results shall also include, but not be limited to, the following as evidence of effectiveness:

- Description of methodology and standards applied;
- Potential variation in scenario interpretation or sources of error in the study;
- Validation of the risk assessment process by an independent and suitable third party;
- Quality system under which the risk assessment was developed;
- The source, suitability and validity of data used within the assessment;
- The knowledge base of persons involved within the assessment;
- System of distribution of results to relevant parties;
- Validation of results by an independent and suitable third party.

LR 1.1.7 The risk and consequences of stratification and rollover of liquefied gas in storage tanks are to be considered. Methods to reduce the possibility of stratification are to be considered, e.g.:

- ability to fill the tank from both the top and bottom;
- recirculation of tank inventory through jet nozzles or other mixing devices.

Methods to detect stratification are also to be considered.

1.2 Definitions

Except where expressly provided otherwise, the following definitions apply to this Part. Additional definitions are provided in Chapters throughout this Part.

1.2.1 **Accommodation spaces** are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobby rooms, barber shops, pantries without cooking appliances and similar spaces.

1.2.2 **'A' class divisions** are divisions as defined in Regulation II-2/3.2 of the SOLAS Convention.

LR 1.2.1 **Administration** is defined in Pt 1, Ch 2,1. For the purpose of classification, the definition of Administration is to be taken as Lloyd's Register (LR).

1.2.3 **Boiling point** is the temperature at which a product exhibits a vapour pressure equal to the atmospheric pressure.

1.2.4 **Breadth**, *B*, in metres, means the maximum breadth of the ship unit, measured amidships to the moulded line of the frame.

LR 1.2.2 For the determination of the scantlings for hull construction, the breadth, *B*, is to be taken as defined in Pt 4, Ch 1,5.

1.2.5 **Cargo area** is that part of the ship unit which contains the cargo containment system and cargo pump and compressor rooms and includes the deck areas over the full length and breadth of the part of the ship unit over these spaces. Where fitted, the cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space are excluded from the cargo area.

1.2.6 **Cargo containment system** is the arrangement for containment of cargo including, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the hold space.

1.2.7 **Cargo control room** is a space used in the control of cargo handling operations.

1.2.8 **Cargoes** are products, listed in Chapter 19, that are carried in bulk by ship units subject to the requirements of this Part.

1.2.9 **Cargo machinery spaces** are the spaces where cargo compressors or pumps, cargo processing units, are located, including those supplying gas fuel to the engine room.

1.2.10 **Cargo pumps** are pumps used for the transfer of liquid cargo, including main pumps, booster pumps, spray pumps, etc.

1.2.11 **Cargo service spaces** are spaces within the cargo area used for workshops, lockers and storerooms that are of more than 2 m^2 in area.

1.2.12 **Cargo tank** is the liquid-tight shell designed to be the primary container of the cargo and includes all such containment systems whether or not they are associated with the insulation or/and the secondary barriers.

1.2.13 **Closed loop sampling** is a cargo sampling system that minimises the escape of cargo vapour to the atmosphere by returning product to the cargo tank during sampling.

1.2.14 **Cofferdam** is the isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

1.2.15 **Control stations** are those spaces in which the ship unit's radio or emergency source of power is located, or where the fire recording or fire control equipment is centralised. This does not include special fire control equipment, which can be most practically located in the cargo area.

1.2.16 **Flammability limits** are the conditions defining the state of fuel oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.

1.2.17 **Flammable products** are those identified by an 'F' in column 'f' in the Table in Chapter 19.

1.2.18 **FSS Code** is the Fire Safety Systems Code meaning the *International Code for Fire Safety Systems* as adopted by the Maritime Safety Committee of the Organisation by Resolution MSC.98(73), as amended.

1.2.19 **Gas carrier** is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in Chapter 19 of the IGC Code.

1.2.20 **Gas Combustion Unit (GCU)** is a means of disposing of excess cargo vapour by thermal oxidation, *see also* 1.2.49.

1.2.21 **Gas consumer** is any unit within the vessel using cargo vapour as a fuel.

1.2.22 **Hazardous area** is an area in which an explosive gas atmosphere is, or may be expected to be present, in quantities that require special precautions for the construction, installation and use of electrical equipment. When a gas atmosphere is present the following hazards may also be present: toxicity, asphyxiation, corrosiveness, reactivity and low temperature; these hazards shall also be taken into account and additional precautions for the ventilation of spaces and protection of the crew will need to be considered.

1.2.23 **Hold space** is the space enclosed by the structure of the ship unit in which a cargo containment system is situated.

1.2.24 **IBC Code** means the *International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk* adopted by the Maritime Safety Committee of the Organisation by Resolution MSC.4(48), as amended.

1.2.25 **Independent** means that a piping or venting system, for example, is in no way connected to another system and that there are no provisions available for the potential connection to other systems.

1.2.26 **Insulation space** is the space, which may or may not be an interbarrier space, occupied wholly or in part by insulation.

1.2.27 **Interbarrier space** is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material.

1.2.28 **Length**, *L*, in metres, is the length as defined in the *International Convention on Load Lines*.

LR 1.2.3 For the determination of the scantlings for hull construction, the Rule length, *L*, is to be taken as defined in Pt 4, Ch 1,5.

1.2.29 **Machinery spaces** are all machinery spaces of category A and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces and the trunks to such spaces.

1.2.30 **Machinery spaces of category A** are those spaces, and trunks to those spaces, which contain:

- *.1* internal combustion machinery used for main propulsion for self-propelled units; or
- *.2* internal combustion machinery used for purposes where such machinery has in the aggregate a total power output of not less than 375 kW; or
- *.3* any oil-fired boiler or oil fuel unit or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

1.2.31 **MARPOL** means the *International Convention for the Prevention of Pollution from Ships*, 1973, as modified by the Protocol of 1978 relating thereto, as amended.

1.2.32 **MARVS** is the maximum allowable relief valve setting of a cargo tank (gauge pressure).

1.2.33 **Non-hazardous area** is an area other than a hazardous area.

1.2.34 **Oil fuel unit** is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar gauge.

1.2.35 **Organisation** is the International Maritime Organization (IMO).

1.2.36 **Permeability** of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

1.2.37 **Primary barrier** is the inner element designed to contain the cargo when the cargo containment system includes two boundaries.

1.2.38 **Products** is the collective term used to cover the list of gases indicated in Chapter 19 of this Part.

1.2.39 **Public spaces** are those portions of the accommodation that are used for halls, dining rooms, lounges and similar permanently enclosed spaces.

1.2.40 **Recognised Organisation** is an Organisation authorised by an Administration in accordance with IMO Resolution A.739(18) *Guidelines for the Authorisation of Organisations acting on Behalf of the Administration*, to act on their behalf to survey, certificate and determine tonnages as required by SOLAS, MARPOL and the Load Line Conventions.

1.2.41 **Recognised standards** are applicable international or national Standards acceptable to LR.

1.2.42 **Relative density** is the ratio of the mass of a volume of a product to the mass of an equal volume of fresh water.

1.2.43 **Secondary barrier** is the liquid-resisting outer element of a cargo containment system, designed to afford temporary containment of any envisaged leakage of liquid cargo through the primary barrier and to prevent the lowering of the temperature of the structure of the ship unit to an unsafe level. Types of secondary barrier are more fully defined in Chapter 4.

1.2.44 **Separate systems** are those cargo piping and vent systems that are not permanently connected to each other.

1.2.45 **Service spaces** are those used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

1.2.46 **SOLAS Convention** means the *International Convention for the Safety of Life at Sea*, 1974, as amended.

1.2.47 **Tank cover** is the protective structure intended either to protect the cargo containment system against damage where it protrudes through the weather deck or to ensure the continuity and integrity of the deck structure.

1.2.48 **Tank dome** is the upward extension of a portion of a cargo tank. In the case of below deck cargo containment systems, the tank dome protrudes through the weather deck or through a tank cover.

1.2.49 **Thermal oxidation method** means a system where the boil-off vapours are utilised as fuel for shipboard use or as a waste heat system, subject to the provisions of Chapter 16 or a system not using the gas as fuel complying with this Part.

1.2.50 **Turret compartments** are those spaces and trunks that contain equipment and machinery for retrieval and release of the disconnectable turret mooring system, high pressure hydraulic operating systems, fire protection arrangements and cargo transfer valves.

1.2.51 **Vapour pressure** is the equilibrium pressure of the saturated vapour above the liquid, expressed in bars absolute at a specified temperature.

LR 1.2.4 **Design vapour pressure** 'P_0' is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

1.2.52 **Void space** is an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, oil fuel tank, cargo pumps or compressor room, or any space in normal use by personnel.

LR 1.3 Alternative arrangements

LR 1.3.1 Alternative arrangements or fittings which are considered to be equivalent to those specified in these Rules will be accepted. Arrangements or systems incorporating features not provided for in these Rules will be specially considered.

LR 1.4 Survey requirements

LR 1.4.1 Ship units engaged in the production, storage and offloading of liquefied gases are to comply with the survey requirements given in Pt 1, Ch 3 and other relevant Parts of the Rules.

LR 1.5 Class notations and descriptive notes

LR 1.5.1 The class notations and descriptive notes applicable to units classed in accordance with these Rules are to be in accordance with Pt 1, Ch 2 and Pt 3, Ch 3,1, to which reference should be made.

LR 1.5.2 Where the requirements of this Part are complied with, additional class notations in respect of the following items will be assigned as appropriate:

- Type of tanks.
- Name(s) of gas(es).
- Maximum vapour pressure.
- Minimum and (where necessary) maximum cargo temperature.
- Design ambient temperatures.

LR 1.5.3 The class notation ✠ **Lloyd's RMC(LG)** is mandatory when reliquefaction and/or refrigeration equipment is fitted. The equipment is to be constructed, installed and tested in accordance with the requirements of Chapter 7 and elsewhere in these Rules. The minimum temperature for which the installation is suitable will be that given in the main notation unless otherwise qualified.

SDA, **FDA** and **CM** notations are already defined within Part 1 and Part 10.

LR 1.6 Information and plans

LR 1.6.1 In addition to the plans required by the relevant Parts of these Rules, the following information and plans are to be submitted, where applicable:

- Full particulars of the intended cargo, or cargoes, including maximum vapour pressures, minimum and (where necessary) maximum liquid temperature and other relevant design conditions.
- General arrangement showing location of cargo tanks and the relative location of oil fuel, water ballast and other tanks.
- Openings in main deck.
- Location of void spaces and dangerous zones: openings and access arrangements.
- Details of hull structure in way of cargo tanks, including support arrangements for tanks and associated pipes and fittings, deck sealing arrangements, etc.
- Distribution of quality and grade of steel, supported by calculations of the determined hull steel temperature. The steel grade and temperature in regions where cold spots are likely to occur (e.g., pump supports and where pipes pass through the deck) are also to be indicated.
- Scantlings, materials, and arrangements of the cargo containment system, including primary and (where fitted) secondary barriers, keying and support arrangements, and attachments of fittings, piping, etc.
- Ladders, suction supports and towers inside cargo tanks (arrangements, materials and loadings).
- Tank dome plans.
- End coamings around dome.
- Particulars of filling, discharging, venting, relieving and inerting arrangements.
- Details of test procedures.
- Temperature control arrangements.
- Such information and data as may be required to enable analysis of the hull and containment system structure to be carried out by direct calculation methods.
- Details of personnel protection equipment to be included on the safety plan as applicable to the ship unit.
- Assumptions and details of direct calculations procedures used in the structural analysis of the hull.
- Where horizontal and vertical girders are used to support the bulkhead, the bulkhead scantlings may be determined using direct calculation procedures. The assumptions made and the calculations are to be submitted.

The following plans and particulars for Type C independent tanks are to be submitted for approval before construction is commenced:

- Nature of cargoes, together with maximum vapour pressures and minimum liquid temperature for which the pressure vessels are to be approved, and proposed hydraulic test pressure.
- Particulars of materials proposed for the construction of the vessels.
- Particulars of refrigeration equipment.
- General arrangement plan showing location of pressure vessels in the ship unit.
- Plans of pressure vessels showing attachments, openings, dimensions, details of welded joints and particulars of proposed stress relief heat treatment.
- Plans of seating, securing arrangements and deck sealing arrangements.

- Plans showing arrangement of mountings, level gauges and number, type and size of safety valves.
- Details of the arrangements proposed to ensure that the tank or cargo temperature cannot be lowered below the minimum design temperature as defined in 4.1.3.
- Plans showing filling, discharging, venting and inerting pipe arrangements, together with particulars of the intended cargo, maximum vapour pressure and minimum liquid temperature.
- Details of calculations and/or model tests are required for the assessment of the tank boundaries with partial filling of tanks.
- Allowable stresses of any materials not covered by Chapter 6 required by 4.18.1.5.
- Details verifying compliance with the periodical examination of the secondary barrier required by 4.6.2.4 if applicable.
- Details of the heating system of the hull structure required by 4.19.1.5 if fitted.
- Specification and plans of the containment system are to be submitted for approval. Plans are to include:
    - Details of insulation material and, if used, any adhesive, sealers, coatings or similar products.
    - Details of insulation arrangement.
    - Internal bearers or steelwork.
    - Tank supports, chocks, etc.
    - Hatch trunks.
    - Attachment and support of insulation and linings.
    - Data and information to enable a heat leakage calculation to be carried out to assess the capacity of the arrangements provided to deal with boil-off, including:
        - Thermal conductivity of insulation between upper ambient and design temperatures.
        - Details of reliquefaction/refrigeration plant duty or maximum allowable boil-off rate for each cargo.
- The proposed procedure for fabrication, storage, handling, erection, quality control and control against harmful exposure to sunlight of insulation materials.
- Calculations and/or analysis of strength of insulation where it is subjected to high mechanical or thermal loads.
- Fatigue and crack propagation properties for insulation in membrane systems are also to be submitted.
- Specifications of the containment system items are to include both those applicable to initial approval of the material, and those applicable to subsequent delivery of batches of material.
- Plans illustrating the means of protection for the steelwork of the ship unit, e.g., drip trays, cladding, etc., at loading manifolds: deck tanks, cargo handling system, etc.

Additional requirements for information and plans may be found in the appropriate Chapters of this Part.

Section

2.1 General

LR 2.1.1 The requirements of this Chapter, except for requirement LR 2.1.2 on ship unit type description, are not classification requirements. However, in cases where LR is requested to do so by an Owner, Operator or Duty Holder, the requirements of this Chapter will be applied, together with any amendments or interpretations adopted by the appropriate National Authority.
Reference should be made to the *Guidelines for Uniform Application of the Survival Requirements of the Bulk Chemical Code and the Gas Carrier Code*.

2.1.1 Ship units shall survive the hydrostatic effects of flooding following assumed hull damage caused by some external force. In addition, to safeguard the ship unit and the environment, the cargo tanks shall be protected from penetration in the case of minor damage to the ship unit resulting, for example, from contact with a shuttle tanker, offshore support vessel or tug, by locating them at specified minimum distances inboard from the shell plating of the ship unit. Both the damage to be assumed and the proximity of the tanks to the shell of the ship unit should be dependent upon the degree of hazard presented by the product to be carried. In addition, the proximity of the cargo tanks to the shell of the ship unit shall be dependent upon the volume of the cargo tank.

LR 2.1.2 Ship units subject to this Part shall be designed to **Type 2G** standard. Type 2G is defined as a ship unit intended for the storage of liquefied hydrocarbon gases as indicated in Chapter 19, that require significant preventive measures to preclude their escape.

LR 2.1.3 For the purpose of this Part, the position of the moulded line for different containment systems is shown in Figs. 2.1(a) to (e).

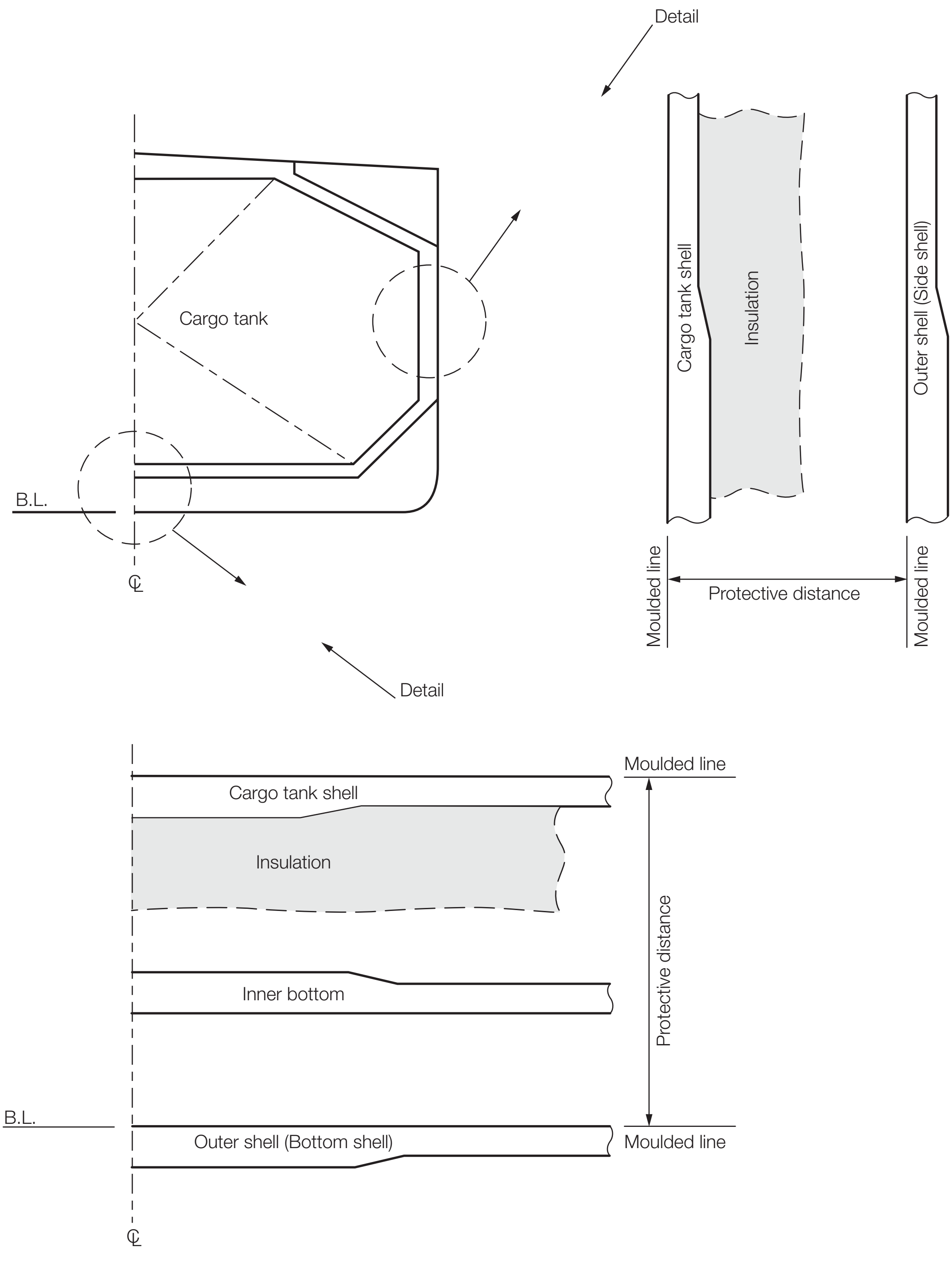


Fig. 2.1(a) Independent prismatic tank, protective distance

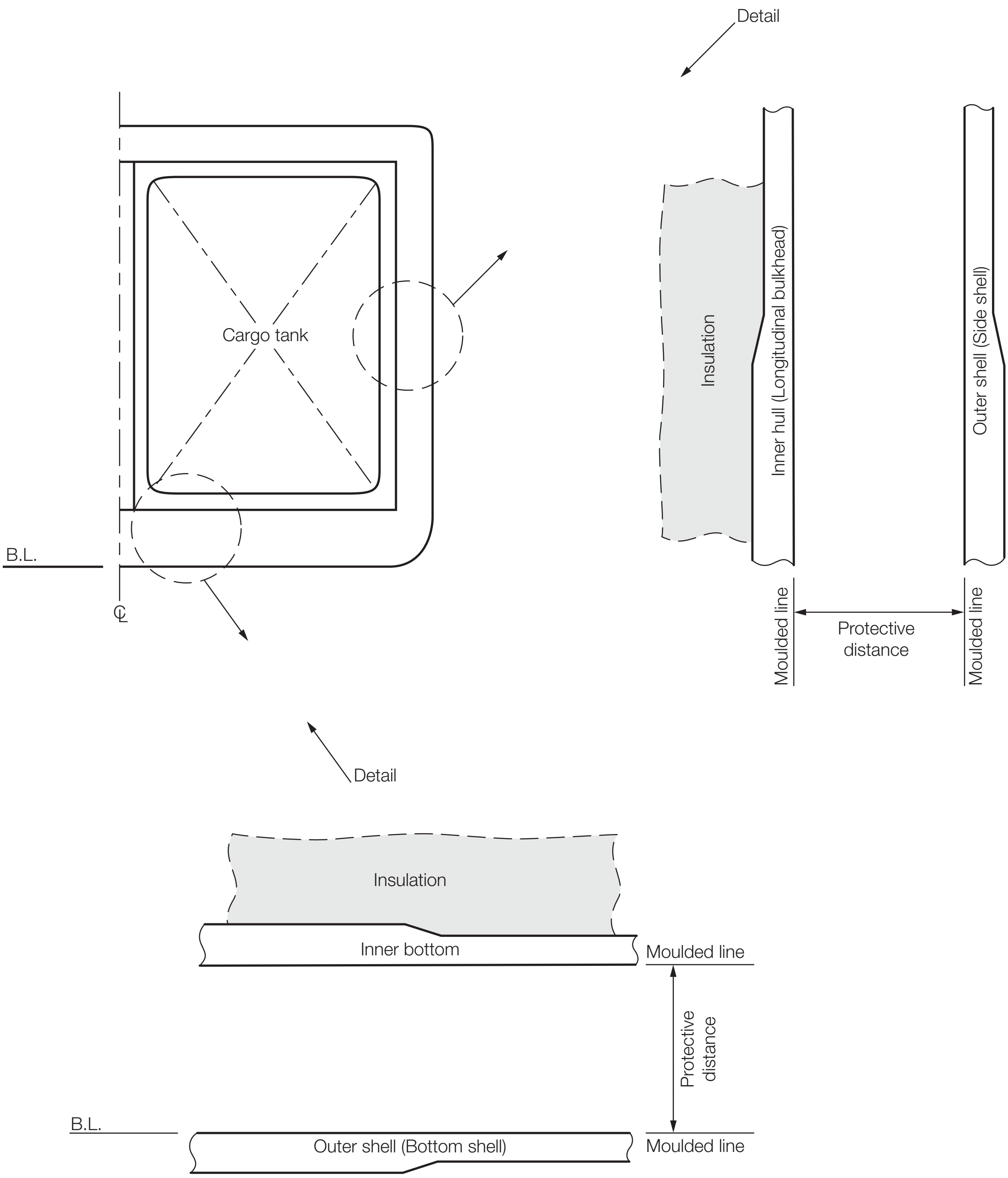


Fig. 2.1(b) Semi-membrane tank, protective distance

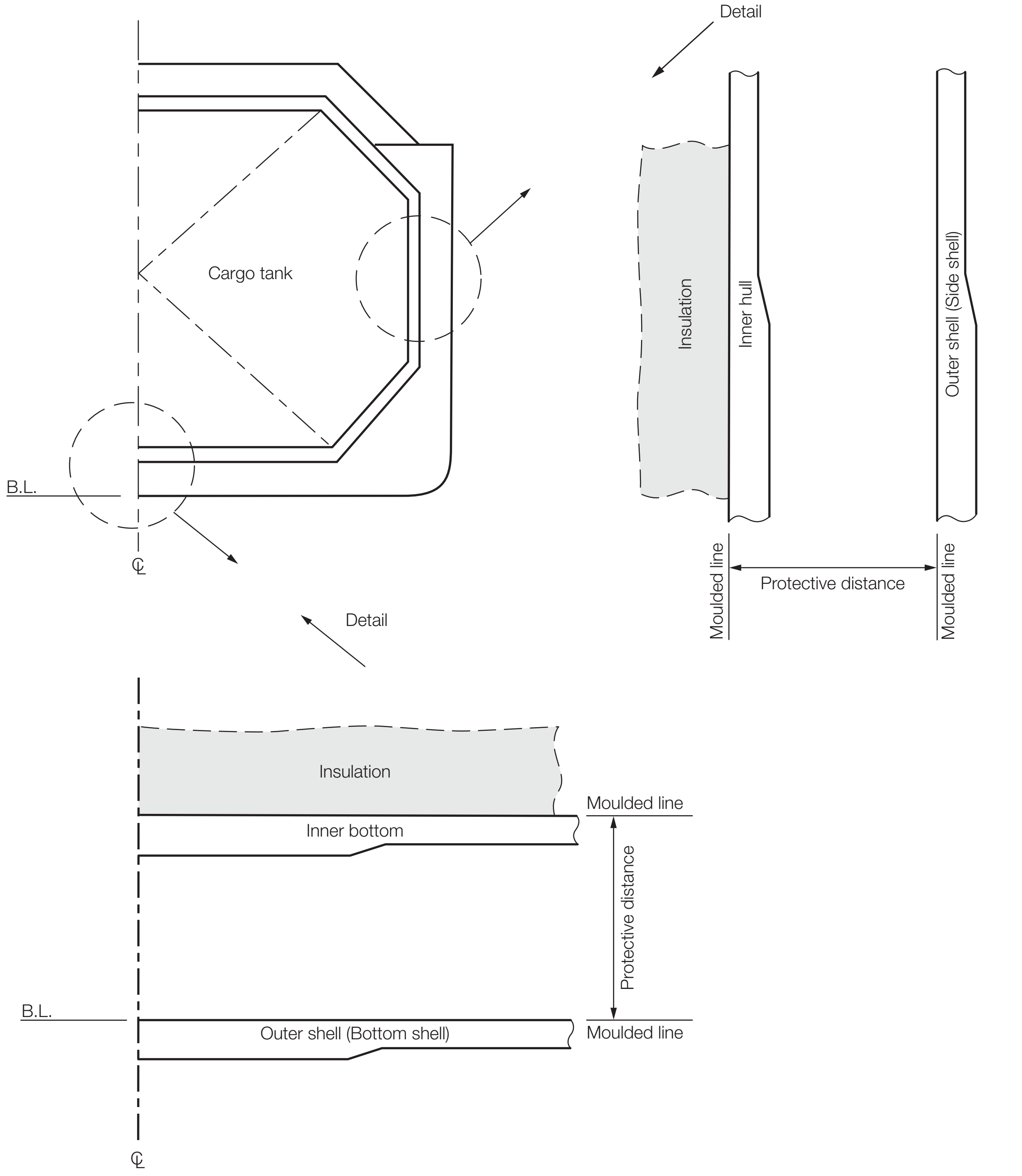


Fig. 2.1(c) Membrane tank, protective distance

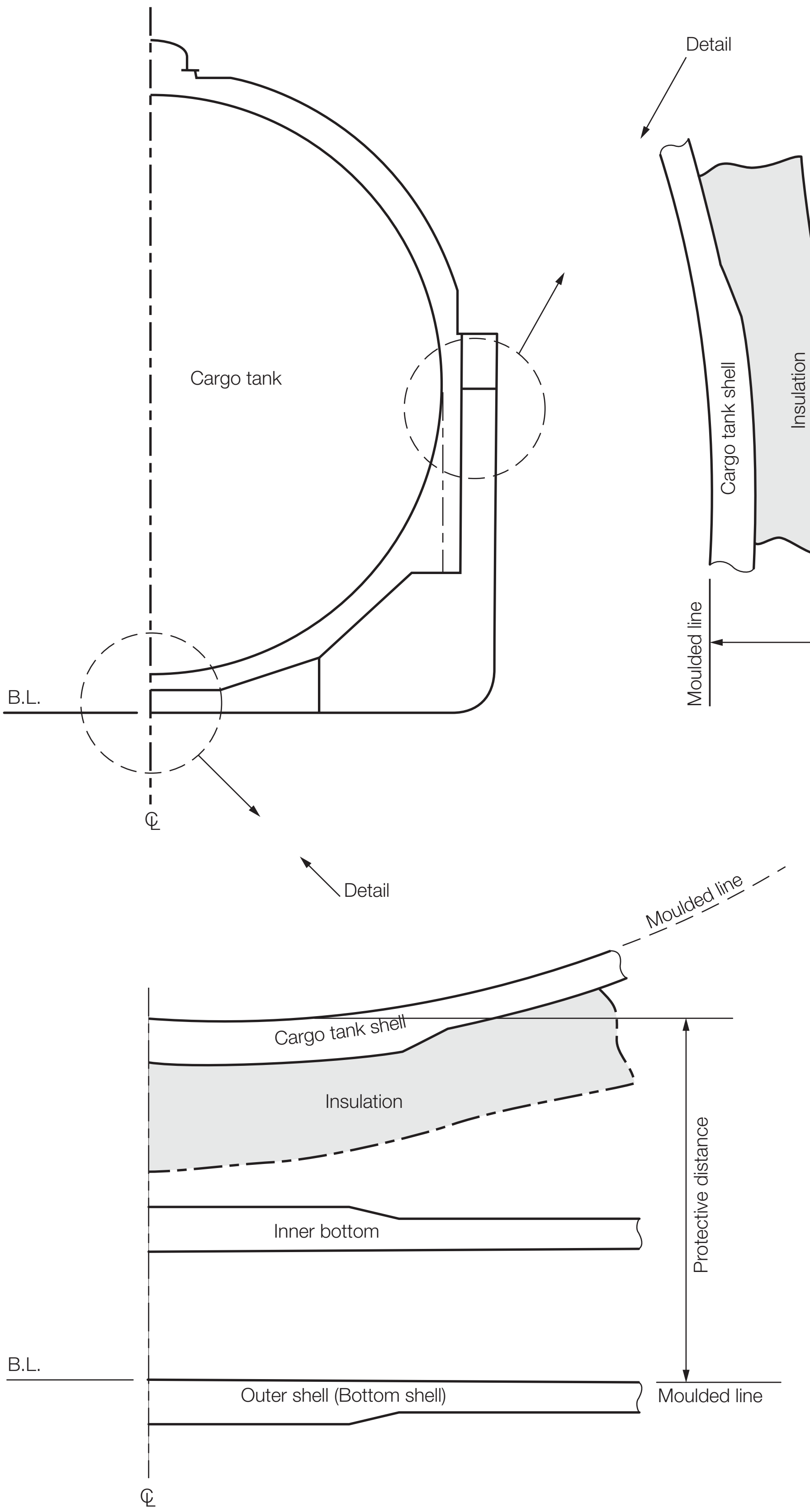


Fig. 2.1(d) Spherical tank, protective distance

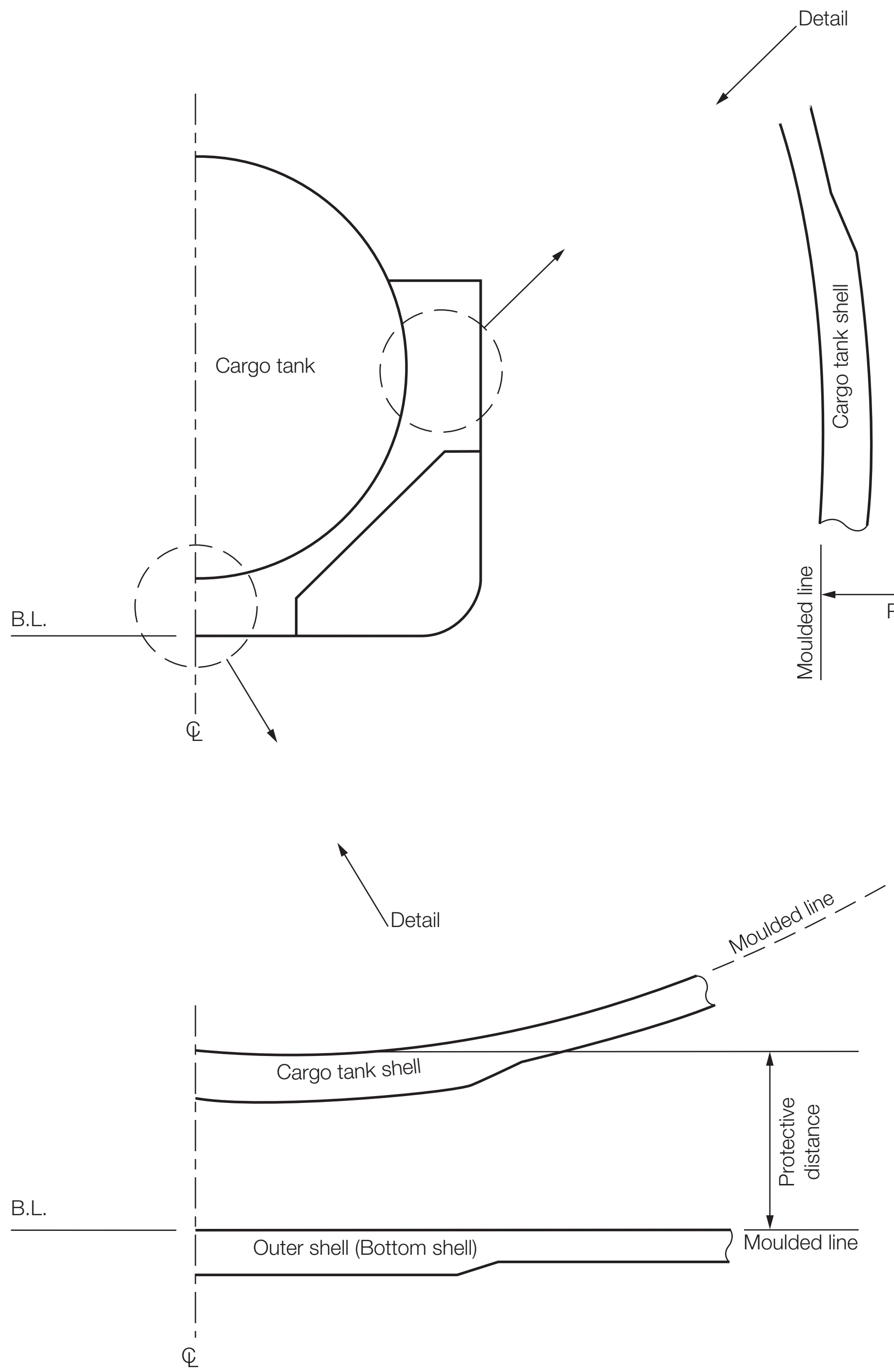


Fig. 2.1(e) Pressure type tank, protective distance

2.2 Freeboard and stability

2.2.1 Ship units subject to this Part may be assigned the minimum freeboard permitted by the International Convention on Load Lines in force. However, the draught associated with the assignment shall not be greater than the maximum draught otherwise permitted by these Rules.

2.2.2 The stability of the ship unit, in all sea-going conditions including inspection/maintenance, ballasting and during loading and unloading cargo, shall comply with the requirements of the *International Code on Intact Stability*.

2.2.3 When calculating the effect of free surfaces of consumable liquids for loading conditions, it shall be assumed that, for each type of liquid, at least one transverse pair or a single centre tank has a free surface. The tank or combination of tanks to be taken into account shall be those where the effect of free surfaces is the greatest. The free surface effect in undamaged compartments shall be calculated by a method according to the *International Code on Intact Stability*.

2.2.4 Solid ballast should not normally be used in double bottom spaces in the cargo area. Where, however, because of stability considerations, the fitting of solid ballast in such spaces becomes unavoidable, its disposition shall be governed by the need to enable access for inspection and to ensure that the impact loads resulting from bottom damage are not directly transmitted to the cargo tank structure.

2.2.5 The Operator of the ship unit shall be supplied with a loading and stability information booklet. This booklet shall contain details of typical service and inspection/maintenance conditions, loading, unloading and ballasting operations, provisions for evaluating other conditions of loading and a summary of the survival capabilities of the ship unit. In addition, the booklet shall contain sufficient information to enable the Operator to load and operate the ship unit in a safe and seaworthy manner. *See also* Pt 1, Ch 2 and Pt 10, Ch 3,1.2.
In addition, the Operator is to be given an approved stability instrument to assess the intact stability and the damage stability condition according to the standard damage cases and the actual damage condition of the ship unit. The stability instrument input data and output results have to be approved by the Administration.

2.2.6 Damage survival capability shall be investigated on the basis of loading information submitted to the Administration for all anticipated conditions of loading and variations in draught and trim. This shall include ballast and, where applicable, cargo heel.

2.3 Damage assumptions

2.3.1 The assumed maximum extent of damage shall be as shown in Table 2.3.1.

2.3.2 **Other damage**

2.3.2.1 If any damage of a lesser extent than the maximum damage specified in Table 2.3.1 would result in a more severe condition, such damage should be assumed.

2.3.2.2 Local damage anywhere in the cargo area extending inboard distance '*d*' as defined in 2.4.1, measured normal to the moulded line of the outer shell shall be considered. Bulkheads shall be assumed damaged, *see* 2.6.1. If a damage of a lesser extent than '*d*' would result in a more severe condition, such damage shall be assumed.

Table 2.3.1 Assumed maximum extent of damage

Location of damage		Assumed maximum extent of damage	
1.	Side damage	To any part of the ship unit	
1.1	Longitudinal extent	$1/3L^{2/3}$ or 14,5 m, whichever is less	
1.2	Transverse extent measured inboard from the moulded line of the outer shell at right angles to the centreline at the level of the summer load line	*B*/5 or 11,5 m, whichever is less	
1.3	Vertical extent from the moulded line of the outer shell at right angles to the centreline at the level of the summer load line	Upwards, without limit	
2.	Bottom damage	For 0,3*L* from the forward perpendicular of the ship unit	To any other part of the ship unit
2.1	Longitudinal extent	$1/3L^{2/3}$ or 14,5 m, whichever is less	$1/3L^{2/3}$ or 14,5 m, whichever is less
2.2	Transverse extent	*B*/6 or 10 m, whichever is less	*B*/6 or 5 m, whichever is less
2.3	Vertical extent	*B*/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline, *see* 2.4.3	*B*/15 or 2 m, whichever is less measured from the moulded line of the bottom shell plating at centreline, *see* 2.4.3

2.4 Location of cargo tanks

2.4.1 Cargo tanks shall be located at the following distances inboard:

Type 2G ship unit: from the moulded line of the bottom shell at centreline not less than the vertical extent of damage specified in 2.3 in Table 2.3.1 and nowhere less than '*d*' (*see* Figs. 2.2 and 2.3), where '*d*' is as follows:

(i) for V_c below or equal to 1000 m^3, d = 0,80 m

(ii) for 1000 m^3 < V_c < 5000 m^3,
d = 0,75 + V_c × 0,20/4000

(iii) for 5000 m^3 ≤ V_c < 30 000 m^3,
d = 0,8 + V_c/25 000

(iv) for V_c ≥ 30 000 m^3, d = 2 m,

where

V_c corresponds to 100 per cent of the gross design volume of the individual cargo tank at 20°C, including domes and appendages. For the purpose of cargo tank protective distances, the cargo tank volume is the aggregate volume of all the parts of tank that have a common bulkhead(s).

NOTE

'*d*' is measured at any cross-section at a right angle from the moulded line of outer shell.

2.4.2 For the purpose of tank location, the vertical extent of bottom damage shall be measured to the inner bottom when membrane or semi membrane tanks are used, otherwise to the bottom of the cargo tanks. The transverse extent of side damage shall be measured to the longitudinal bulkhead when membrane or semi membrane tanks are used, otherwise to the side of the cargo tanks. The distances indicated in 2.3 and 2.4 shall be applied as in Figs. 2.1(a) to (e). These distances shall be measured plate to plate, from the moulded line to the moulded line, excluding insulation.

2.4.3 Suction wells installed in cargo tanks may protrude into the vertical extent of bottom damage specified in 2.3 in Table 2.3.1 provided that such wells are as small as practicable and the protrusion below the inner bottom plating does not exceed 25 per cent of the depth of the double bottom or 350 mm, whichever is less. Where there is no double bottom, the protrusion below the upper limit of bottom damage shall not exceed 350 mm. Suction wells installed in accordance with this paragraph may be ignored when determining the compartments affected by damage.

LR 2.4.1 Cargo tanks shall not be located forward of the collision bulkhead.

LR 2.4.2 When more than one independent tank is fitted in a space, sufficient clearance is to be left between the tanks for inspection or repairs.

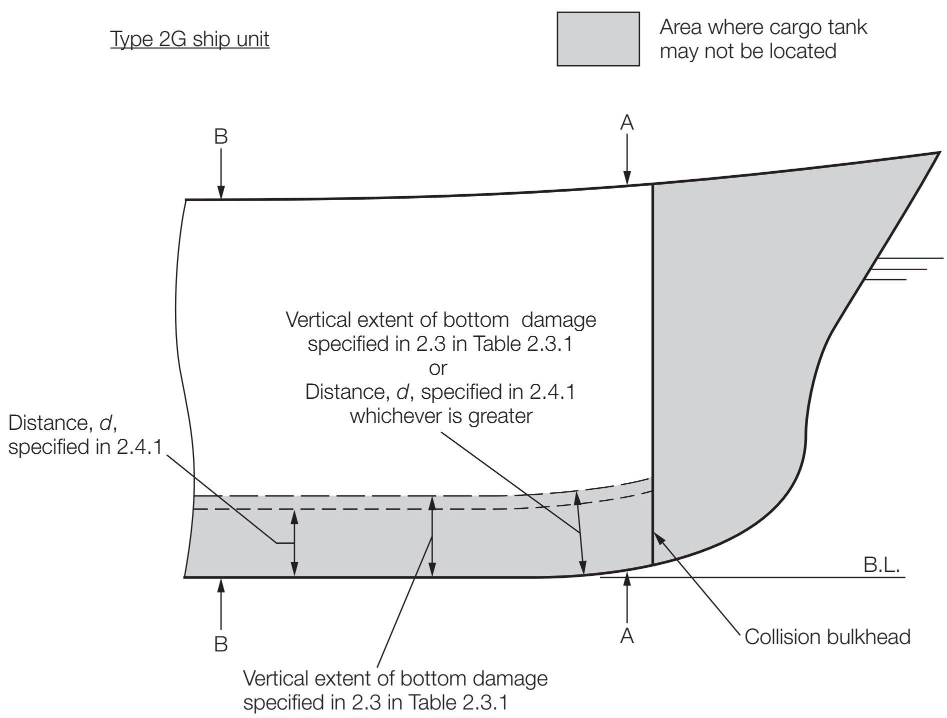


Fig. 2.2 Cargo tank location requirements, centreline profile, Type 2G ship units

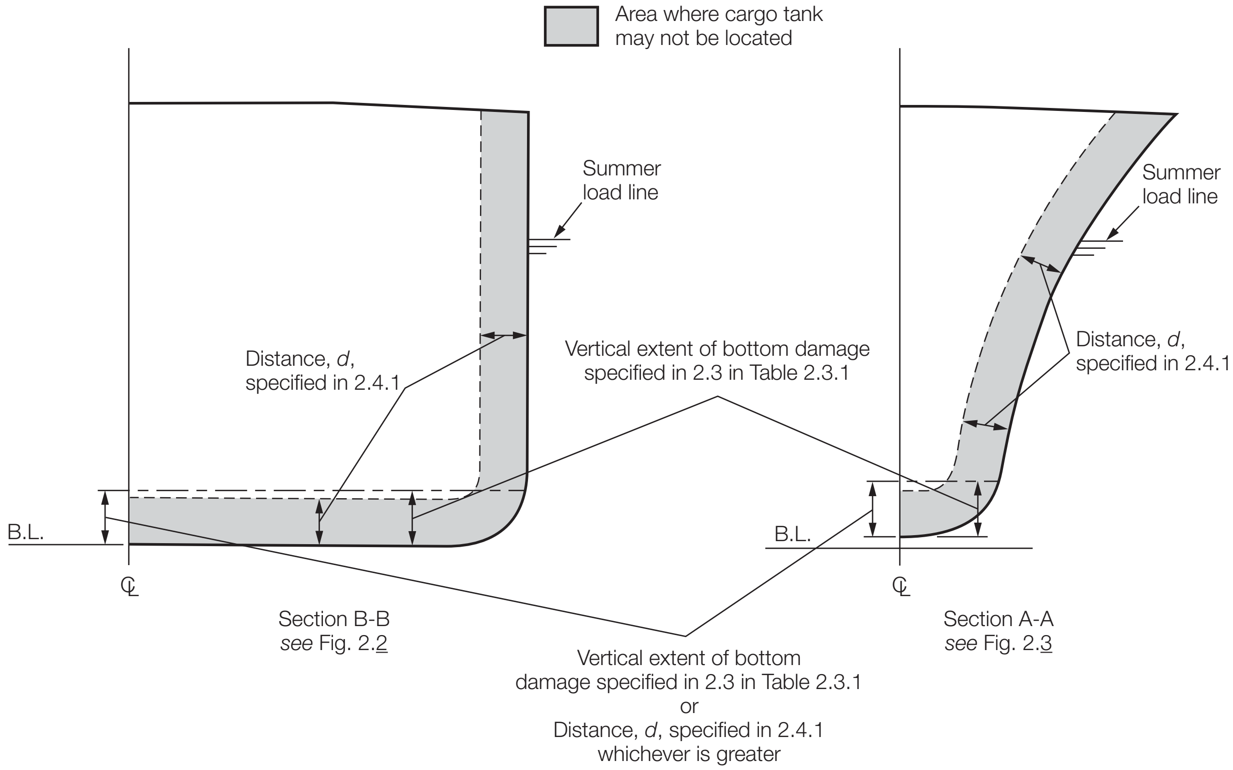


Fig. 2.3 Cargo tank location requirements, transverse sections, Type 2G ship units

2.5 Flood assumptions

2.5.1 The requirements of 2.7 shall be confirmed by calculations that take into consideration the design characteristics of the ship unit, the arrangements, configuration and contents of the damaged compartments, the distribution, relative densities and the free surface effects of liquids and the draught and trim for all conditions of loading.

2.5.2 The permeability of spaces assumed to be damaged shall be as given in Table 2.5.1.

Table 2.5.1 Permeability of spaces assumed to be damaged

Space	Permeability
Stores	0,6
Accommodation	0,95
Machinery	0,85
Voids	0,95
Hold spaces	0,95 *see* Note 1
Consumable liquids	0 to 0,95 *see* Note 2
Other liquids	0 to 0,95 *see* Note 2

NOTES
1. Other values of permeability can be considered based on detailed calculations; refer to MSC/Circ.651 *Interpretations of part B-1 of SOLAS Chapter II-1*.
2. The permeability of partially filled compartments shall be consistent with the amount of liquid carried in the compartment.

2.5.3 Wherever damage penetrates a tank containing liquids, it shall be assumed that the contents are completely lost from that compartment and replaced by saltwater up to the level of the final plane of equilibrium.

2.5.4 The ship unit shall be designed to keep unsymmetrical flooding to the minimum consistent with efficient arrangements.

2.5.5 Equalisation arrangements requiring mechanical aids such as valves or cross-levelling pipes, if fitted, shall not be considered for the purpose of reducing an angle of heel or attaining the minimum range of residual stability to meet the requirements of 2.7.1 and sufficient residual stability shall be maintained during all stages where equalisation is used. Spaces linked by ducts of large cross-sectional area may be considered to be common.

2.5.6 If pipes, ducts, trunks or tunnels are situated within the assumed extent of damage penetration, as defined in 2.3, arrangements shall be such that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage.

2.5.7 The buoyancy of any superstructure directly above the side damage shall be disregarded. However, the unflooded parts of superstructures beyond the extent of damage may be taken into consideration provided that:

.1 they are separated from the damaged space by watertight divisions and the requirements of 2.7.1.1 in respect of these intact spaces are complied with; and

.2 openings in such divisions are capable of being closed by remotely operated sliding watertight doors and unprotected openings are not immersed within the minimum range of residual stability required in 2.7.2.1. However, the immersion of any other openings capable of being closed weathertight may be permitted.

2.6 Standard of damage

2.6.1 Type 2G ship units shall be capable of surviving the damage indicated in 2.3 anywhere in its length with the flooding assumptions in 2.5.

2.7 Survival requirements

Ship units shall be capable of surviving the assumed damage specified in 2.3, to the standard provided in 2.6, in a condition of stable equilibrium and shall satisfy the following criteria.

2.7.1 In any stage of flooding:

.1 the waterline, taking into account sinkage, heel and trim, shall be below the lower edge of any opening through which progressive flooding or downflooding may take place. Such openings shall include air pipes and openings that are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers and watertight flush scuttles, small watertight cargo tank hatch covers that maintain the high integrity of the deck, remotely operated watertight sliding doors and sidescuttles of the non opening type;

.2 the maximum angle of heel due to unsymmetrical flooding shall not exceed 25°, except that this angle may be increased to 30° if no deck immersion occurs; and

.3 the residual stability during intermediate stages of flooding shall not be significantly less than that required by 2.7.2.1.

2.7.2 At final equilibrium after flooding:

.1 the righting lever curve shall have a minimum range of 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 0,1 m within the 20° range; the area under the curve within this range shall not be less than 0,0175 m radians. The 20° range may be measured from any angle commencing between the position of equilibrium and the angle of 25° (or 30° if no deck immersion occurs). Unprotected openings shall not be immersed within this range unless the space concerned is assumed to be flooded. Within this range, the immersion of any of the openings listed in 2.7.1.1 and other openings capable of being closed weathertight may be permitted; and

.2 the emergency source of power shall be capable of operating.

Section

3.1 Segregation of the cargo area and cargo tank holds

LR 3.1.1 In addition to the requirements outlined in this Section, the requirements of Pt 3, Ch 2 are to be complied with.

3.1.1 Hold spaces shall be segregated from machinery and boiler spaces, accommodation spaces, service spaces, control stations, chain lockers, domestic water tanks and from stores. Hold spaces shall be located forward of machinery spaces of category A. Alternative arrangements, including locating machinery spaces of category A forward, may be accepted, based on SOLAS, Regulation 17, after further consideration of involved risks, including that of cargo release and the means of mitigation.

3.1.2 Where cargo is carried in a cargo containment system not requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1 or spaces either below or outboard of the hold spaces may be effected by cofferdams, oil fuel tanks or a single gastight bulkhead of all-welded construction forming an A-60 class division. A gastight A-0 class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.3 Where cargo is carried in a cargo containment system requiring a complete or partial secondary barrier, segregation of hold spaces from spaces referred to in 3.1.1, or spaces either below or outboard of the hold spaces that contain a source of ignition or fire hazard, shall be effected by cofferdams or oil fuel tanks. A gastight A-0 class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.4 Segregation of turret compartments from spaces referred to in 3.1.1, or spaces either below or outboard of the turret compartment that contain a source of ignition or fire hazard, shall be effected by cofferdams or an A-60 class division. A gastight A-0 class division is acceptable if there is no source of ignition or fire hazard in the adjoining spaces.

3.1.5 In addition, the risk of fire propagation from turret compartments to adjacent spaces shall be evaluated by a risk analysis, *see* Chapter 1 and Pt 1, Ch 5, and further preventive measures, such as the arrangement of a cofferdam around the turret compartment, shall be provided if needed.

3.1.6 When cargo is carried in a cargo containment system requiring a complete or partial secondary barrier:

.1 at temperatures below –10°C, hold spaces shall be segregated from the sea by a double bottom; and

.2 at temperatures below –55°C, the ship unit shall also have a longitudinal bulkhead forming side tanks.

3.1.7 Arrangements shall be made for sealing the weather decks in way of openings for cargo containment systems.

LR 3.1.2 Cargo tank holds are to be separated from each other by single bulkheads of all welded construction. Where, however, the design temperature as defined in Chapter 4 is below –55°C, cofferdams are to be adopted unless the cargo is carried in independent tanks and alternative arrangements are made to ensure the bulkhead cannot be cooled to below –55°C. Cofferdams may be used as ballast tanks, subject to approval by Lloyd's Register (LR).

3.2 Accommodation, service and machinery spaces and control stations

3.2.1 No accommodation space, service space (except cargo service spaces, *see* LR 3.2.1 or topsides service spaces) or control station shall be located within the cargo area. The bulkhead of accommodation spaces, service spaces (except cargo and topsides service spaces) or control stations that face the cargo area shall be so located as to avoid the entry of gas from the hold space to such spaces through a single failure of a deck or bulkhead on a ship unit having a containment system requiring a secondary barrier. Cargo, topsides and turret service spaces (i.e. workshops, store rooms, etc.) and machinery spaces located above the cargo storage areas, which are impacted by hazardous areas, are to be in accordance with the requirements of Pt 7, Ch 2,4.

LR 3.2.1 Cargo service spaces as defined in Ch 1,1.2 may be situated within cargo areas, provided all other relevant requirements of these Rules are complied with.

3.2.2 In order to guard against the danger of hazardous vapours, due consideration should be given to the location of air intakes/outlets and openings into accommodation, service and machinery spaces and control stations in relation to cargo piping, cargo vent systems and machinery space exhausts from gas burning arrangements. *See* Pt 7, Ch 2, regarding the air intakes/outlets and openings to enclosed non hazardous areas.

3.2.3 As far as practicable, access doors or other openings should not be provided between a non-hazardous space and a hazardous area or space, or between Zone 2 and a Zone 1 space, as defined in Chapter 10. Where such openings are necessary, access from the accommodation, service spaces, machinery spaces or any other defined non hazardous enclosed areas on topsides, deck, turret or within the hull are to be in compliance with Pt 7, Ch 2,4.

3.2.4 Entrances, air inlets and openings to accommodation spaces and hull spaces and control stations shall not face the cargo area. They shall be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse or on both at a distance of at least 4 per cent of the load line length, *L*, as defined in 1.2 of the ship unit but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m.

.1 Windows and sidescuttles facing the cargo area and on the sides of the superstructures or deckhouses within the distance mentioned above shall be of the fixed (non-opening) type. Wheelhouse windows for navigational purposes may be non-fixed and wheelhouse doors may be located within the above limits so long as they are designed in a manner such that a rapid and efficient gas and vapour tightening of the wheelhouse can be ensured.

.2 Access to forecastle spaces containing sources of ignition may be permitted through door access facing the cargo area, provided the doors are either located a suitable distance outside hazardous areas as defined in Chapter 10 or are in accordance with the requirements of Pt 7, Ch 2,4.

3.2.5 Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in 3.2.4, except wheelhouse windows for navigational purposes where applicable, shall be constructed to at least A-60 class. Wheelhouse windows for navigational purposes shall be constructed to at least A-0 class (for external fire load). Sidescuttles in the shell below the uppermost continuous deck and in the first tier of the superstructure or deckhouse shall be of fixed (non-opening) type. It should be noted that the above minimum class of windows should be confirmed for their suitability within the installation Fire and Explosion Evaluation (FEE). If necessary, higher rated windows or alternative designs without windows may be required dependent upon the findings of the FEE.

3.2.6 All air intakes, outlets and other openings into the accommodation spaces, service spaces and control stations shall be fitted with closing devices. For toxic gases, they shall be operated from inside the space. Air intakes and outlets and the protection against gas ingress into all accommodation spaces, service spaces and control stations are to be in accordance with the requirements of Pt 7, Ch 1,5 and Pt 7, Ch 2,6.1.3.

3.2.7 Control rooms and machinery spaces of turret systems may be located in the cargo area forward or aft of cargo tanks in ship units with such installations. Access to such spaces containing sources of ignition may be permitted through doors facing the cargo area, provided the doors are located outside hazardous areas or access is in accordance with the requirements of Pt 7, Ch 2,4.

LR 3.2.2 Any topsides or turret service spaces or machinery spaces shall generally be treated for the purpose of fire containment according to SOLAS Regulation II-2/9.2.4. However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy.

LR 3.2.3 Arrangements of any topsides or turret service spaces or machinery spaces should ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors shall be provided in each service space, except that a single escape route may be accepted where the maximum travel distance to the door is 5 m or less.

3.3 Cargo machinery spaces and turret compartments

3.3.1 Cargo machinery spaces shall be situated above the weather deck and located within the cargo area. Cargo machinery spaces and turret compartments shall be treated as cargo pump rooms for the purpose of fire protection according to SOLAS Regulation II-2/9.2.4, and for the purpose of prevention of potential explosion according to SOLAS II-2/4.5.10.

3.3.2 When cargo machinery spaces are located at the after end of the aftermost hold space or at the forward end of the forwardmost hold space, the limits of the cargo area, as defined in 1.2, shall be extended to include the cargo machinery spaces for the full breadth and depth of the ship unit and the deck areas above those spaces.

3.3.3 Where the limits of the cargo area are extended by 3.3.2, the bulkhead that separates the cargo machinery spaces from accommodation and service spaces, control stations and machinery spaces of category A shall be located so as to avoid the entry of gas to these spaces through a single failure of a deck or bulkhead.

3.3.4 Cargo compressors and cargo pumps may be driven by electric motors in an adjacent non-hazardous space separated by a bulkhead or deck if the seal around the bulkhead penetration ensures effective gas-tight segregation of the two spaces. Alternatively such equipment may be driven by certified safe electric motors adjacent to them if the electrical installation complies with the requirements of Chapter 10.

3.3.5 Arrangements of cargo machinery spaces and turret compartments should ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. At least two widely separated escape routes and doors shall be provided in cargo machinery spaces, except that a single escape route may be accepted where the maximum travel distance to the door is 5 m or less.

3.3.6 All valves necessary for cargo handling shall be readily accessible to personnel wearing protective clothing. Suitable arrangements shall be made to deal with drainage of pump and compressor rooms.

3.3.7 Turret compartments shall be designed to retain their structural integrity in case of explosion or uncontrolled high pressure gas release (overpressure and/or brittle fracture), the characteristics of which shall be substantiated on the basis of a risk analysis with due consideration of the capabilities of the pressure-relieving devices. *See also* Pt 10, Ch 2,5.2.

3.4 Cargo control rooms

3.4.1 Any cargo control room shall be above the weather deck and may be located in the cargo area. The cargo control room may be located within the accommodation spaces, service spaces or control stations provided the following conditions are complied with:

.1 the cargo control room is a non-hazardous area;

.2.1 if the entrance complies with 3.2.4, the control room may have access to the spaces described above;

.2.2 if the entrance does not comply with 3.2.4 the cargo control room shall have no access to the spaces described above and the boundaries for such spaces shall be insulated to at least A-60 class or higher. It should be noted that the minimum fire class of a cargo control room's boundaries should be confirmed for their suitability within the installation Fire and Explosion Evaluation (FEE). If necessary, higher rated fire boundaries may be required, dependent upon the findings of the FEE.

3.4.2 If the cargo control room is designed to be a non-hazardous area, instrumentation should, as far as possible, be by indirect reading systems and shall in any case be designed to prevent any escape of gas into the atmosphere of that space. Location of the gas detection system within the cargo control room will not cause the room to be classified as a hazardous area, if installed in accordance with 13,6.9.

3.4.3 If the cargo control room for ship units carrying flammable cargoes is classified as a hazardous area, sources of ignition shall be excluded and any electrical equipment shall be installed in accordance with Chapter 10.

3.5 Access to spaces in the cargo area

3.5.1 Visual inspection of at least one side of the inner hull structure shall be possible without the removal of any fixed structure or fitting. If such a visual inspection, whether or not combined with those inspections required in 3.5.2 or Chapter 4, is only possible at the outer face of the inner hull, the inner hull shall not be a fuel oil tank boundary wall.

3.5.2 Inspection of one side of any insulation in hold spaces shall be possible. If the integrity of the insulation system can be verified by inspection of the outside of the hold space boundary when tanks are at service temperature, inspection of one side of the insulation in the hold space need not be required.

3.5.3 Arrangements for hold spaces, void spaces, cargo tanks and other spaces defined as hazardous areas in Chapter 10, shall be such as to allow entry and inspection of any such space by personnel wearing protective clothing and breathing apparatus and shall also allow for the evacuation of injured and/or unconscious personnel. Such arrangements shall comply with the following:

.1 Access shall be provided:

.1.1 To all cargo tanks, access shall be direct from the weather deck.

.1.2 Access through horizontal openings¸ hatches or manholes, the dimensions shall be sufficient to allow a person wearing a breathing apparatus to ascend or descend any ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the space the minimum clear opening shall be not less than 600 mm × 600 mm; and

.1.3 Access through vertical openings or manholes providing passage through the length and breadth of the space, the minimum clear opening shall be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom plating unless gratings or other footholds are provided.

.1.4 Circular access openings to Type C tanks shall have a diameter of not less than 600 mm.

.2 The dimensions referred to in 3.5.3.1.2 and 3.5.3.1.3 may be decreased if the requirements of 3.5.3 can be met to the satisfaction of the Administration.

.3 Where cargo is carried in a containment system requiring a secondary barrier the requirements of 3.5.3.1.2 and 3.5.3.1.3 do not apply to spaces separated from a hold space by a single gastight steel boundary. Such spaces shall be provided only with direct or indirect access from the weather deck, not including any enclosed non hazardous area.

.4 Access required for inspection shall be provided as follows:

.4.1 Designated access through structures below and above cargo tanks shall have at least the cross sections as required by 3.5.3.1.3

.5 For the purpose of 3.5.1 or 3.5.2 the following shall apply:

.5.1 Where it is required to pass between the surface to be inspected, flat or curved, and structures such as deck beams, stiffeners, frames, girders, etc., the distance between that surface and the free edge of the structural elements shall be at least 380 mm. The distance between the surface to be inspected and the surface to which the above structural elements are fitted, e.g., deck, bulkhead or shell, shall be at least 450 mm for a curved tank surface (e.g. for a Type C tank) or 600 mm for a flat tank surface (e.g., for a Type A tank). (*See* Fig. 3.1).

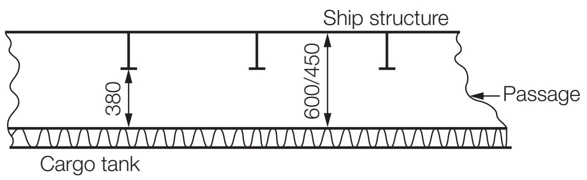


Fig. 3.1
Minimum passage clearance for tank inspection in way of ship structural members

.5.2 Where it is not required to pass between the surface to be inspected and any part of the structure, for visibility reasons the distance between the free edge of that structural element and the surface to be inspected shall be at least 50 mm or half the breadth of the face plate of the structure, whichever is the larger. *See* Fig. 3.2.

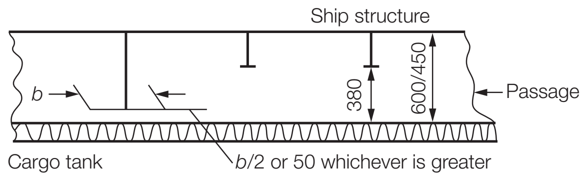


Fig. 3.2
Minimum visibility clearance for tank inspection in way of ship structural members

.5.3 For inspection of a curved surface where it is required to pass between that surface and another surface, flat or curved, to which no structural elements are fitted, the distance between both surfaces shall be at least 380 mm, *see* Fig. 3.3. Where it is not required to pass between that curved surface and another surface, a smaller distance than 380 mm may be accepted taking into account the shape of the curved surface.

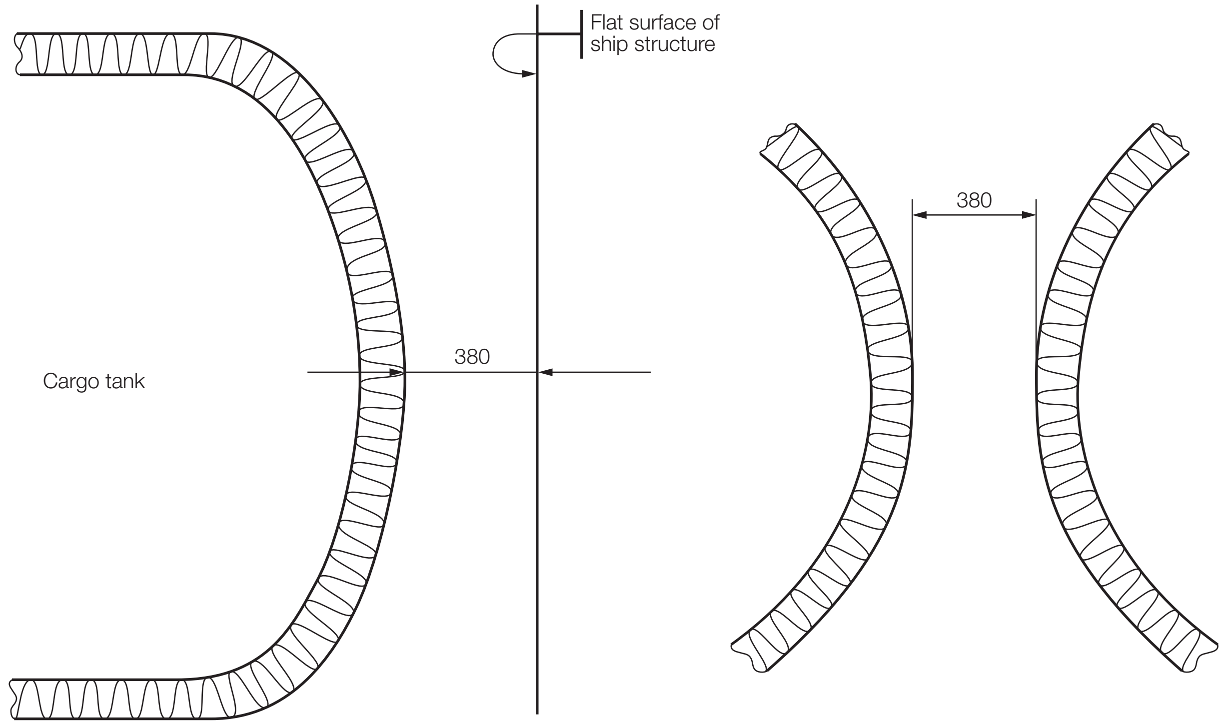


Fig. 3.3 Minimum passage clearance for tank inspection between surfaces

.5.4 For inspection of an approximately flat surface where it is required to pass between two approximately flat and approximately parallel surfaces, to which no structural elements are fitted, the distance between those surfaces shall be at least 600 mm. Where fixed access ladders are fitted a clearance of at least 450 mm shall be provided for access. *See* Fig. 3.4.

.5.5 The minimum distances between a cargo tank sump and adjacent double bottom structure in way of a suction well shall not be less than those shown in Fig. 3.5. If there is no suction well the distance between the cargo tank sump and the inner bottom shall not be less than 50 mm.

NOTE

Fig. 3.5 shows that the distance between the plane surfaces of the sump and the well is a minimum of 150 mm and that the clearance between the edge between the inner bottom plate, and the vertical side of the well and the knuckle point between the spherical or circular surface and sump of the tank is at least 380 mm.

.5.6 The distance between a cargo tank dome and deck structures shall not be less than 150 mm. *See* Fig. 3.6.

.5.7 Fixed or portable staging shall be installed as necessary for inspection of cargo tanks, cargo tank supports and restraints (e.g., anti-pitching, anti-rolling and anti-flotation chocks), cargo tank insulation etc. This staging shall not impair the clearances specified in 3.5.3.5.1 to 3.5.3.5.4.

.5.8 If fixed or portable ventilation ducting is to be fitted in compliance with 12.2, such ducting shall not impair the distances required under 3.5.3.5.1 to 3.5.3.5.4.

LR 3.5.1 In general, the requirements for minimum clear opening given in 3.5.3.1.2 and 3.5.3.1.3 are also to be adhered to for spaces separated by a single gastight steel boundary from a hold space where cargo is carried in a cargo containment system requiring a secondary barrier. Reference is made to IACS *Interpretations of the IMO Code for the Construction and Equipment of Ships carrying Liquefied Gases in Bulk No. GC6*.

For ship units complying with the requirements for Type A independent tanks, manholes will not be permitted through the secondary barrier, except through the upper deck in regions which are above the predicted surface of the cargo assuming total failure of the cargo tank and the ship unit at 30 degrees heel port or starboard. Alternative structural arrangement will be specially considered.

3.5.4 As far as practicable, access from the open weather deck to non-hazardous areas are to be located outside hazardous areas as defined in Chapter 10. Where it is not possible to located a weather deck non hazardous enclosure access doorway in a non hazardous area, access is to be in compliance with Pt 7, Ch 2,4.

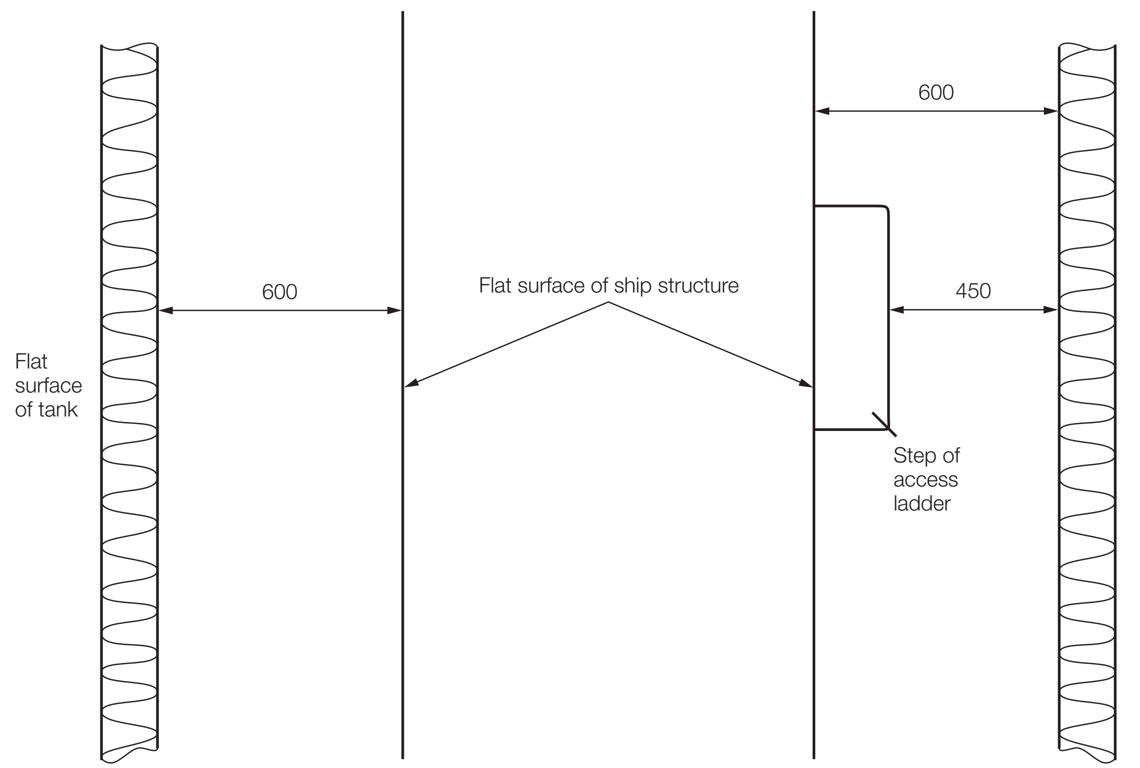


Fig. 3.4 Minimum access clearance in way of fixed access ladders

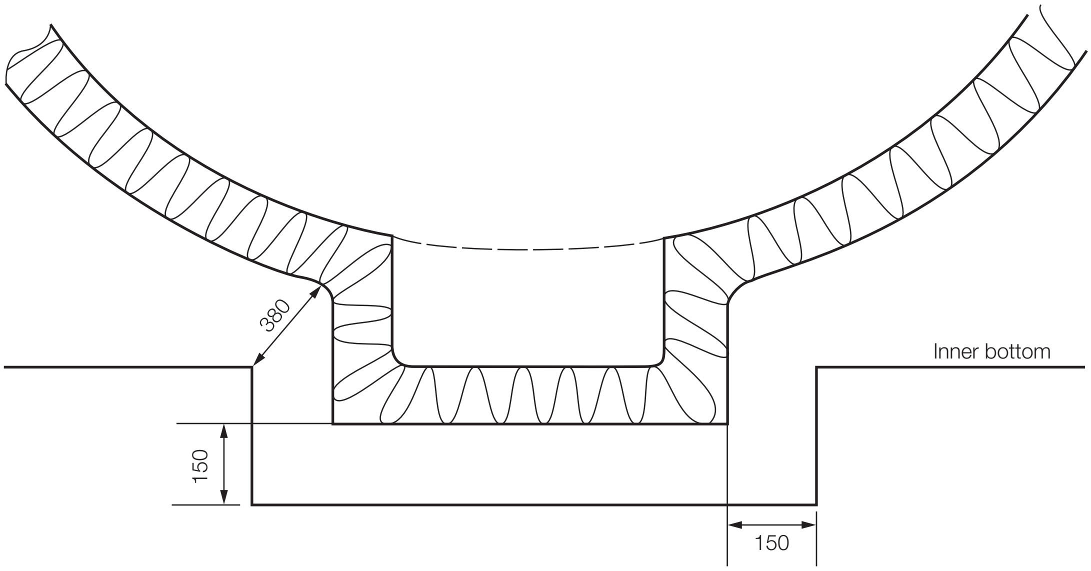


Fig. 3.5
Minimum distances between cargo tank sump and adjacent double bottom structure in way of a section well

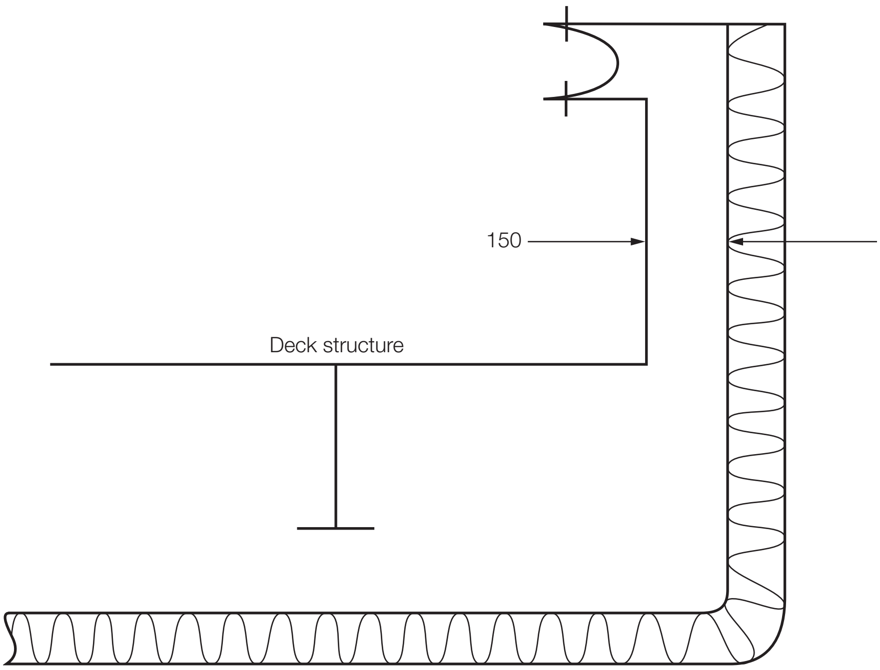


Fig. 3.6 Minimum distance between cargo tank dome and deck structure

3.5.5 Turret compartments shall be arranged with two independent means of access/egress. The access/egress routes are to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed. A single escape route may be accepted for turret compartments where the maximum travel distance to the door is 5 m or less.

3.5.6 Access from a hazardous area below the hull weather deck to a non-hazardous area should be avoided. However, where it is not practicable access is to be in compliance with Pt 7, Ch 2,4.

3.6 Airlocks

3.6.1 Access between hazardous areas on the open weather deck and non-hazardous spaces shall be by means of an airlock. This shall consist of two self closing, substantially gastight, steel doors without any holding back arrangements, capable of maintaining the over pressure, at least 1,5 m but no more than 2,5 m apart. The airlock space shall be artificially ventilated from a non-hazardous area and maintained at an overpressure to the hazardous area on the weather deck.

3.6.2 Where spaces are protected by pressurisation, the ventilation is to be designed and installed in accordance with Pt 7, Ch 1,5 and Pt 7, Ch 2,6.1.3 or an equivalent National or Internationally recognised Standard, submitted to LR for approval.

3.6.3 The relative air pressure within the non hazardous enclosure is to be continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given at a manned control station.

3.6.4 For electrical equipment that is located in enclosed non hazardous spaces, is not certified for operation in a Zone 1 hazardous area and does not have to remain operational during catastrophic conditions (i.e., major hydrocarbon release scenarios), consideration shall be given to de-energising this equipment in case of confirmed loss of overpressure in the space. If the flammable gas is subsequently detected within the area all non emergency electrical items of equipment are to be de-energised immediately.

3.6.5 Electrical equipment for manoeuvring, anchoring and mooring as well as emergency fire pumps that are located in spaces protected by airlocks shall be of a certified safe type.

3.6.6 The airlock space shall be monitored for cargo vapours, *see also* 13.6.2.

3.6.7 Subject to the requirements of the International Convention on Load Lines as amended, the door sill shall not be less than 300 mm in height.

LR 3.6.1 Air locks are to ensure safe unrestricted access for personnel wearing protective clothing and breathing apparatus, and in the event of injury to allow unconscious personnel to be removed.

3.7 Bilge, ballast and oil fuel arrangements

3.7.1 Where cargo is carried in a cargo containment system not requiring a secondary barrier, suitable drainage arrangements for the hold spaces that are not connected with the machinery space shall be provided. Means of detecting any leakage shall be provided.

3.7.2 Where there is a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided. The suction shall not lead to pumps inside the machinery space. Means of detecting such leakage shall be provided.

3.7.3 The hold or interbarrier spaces of Type A independent tank ship units shall be provided with a drainage system suitable for handling liquid cargo in the event of cargo tank leakage or rupture. Such arrangements shall provide for the return of any cargo leakage to the liquid cargo piping.

3.7.4 Arrangements referred to in 3.7.3 shall be provided with a removable spool piece.

3.7.5 Ballast spaces, including wet duct keels used as ballast piping, fuel oil tanks and non-hazardous spaces, may be connected to pumps in the machinery spaces. Dry duct keels with ballast piping passing through may be connected to pumps in the machinery spaces, provided the connections are led directly to the pumps and the discharge from the pumps is led directly overboard with no valves or manifolds in either line that could connect the line from the duct keel to lines serving non-hazardous spaces. Pump vents shall not be open to machinery spaces.

3.8 Tandem and side-by-side loading and unloading arrangements

3.8.1 Subject to the requirements of this Section and Chapter 5, cargo piping may be arranged to permit tandem (bow or stern) and side-by-side loading and unloading.

3.8.2 Portable arrangements shall not be permitted.

3.8.3 Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and controls stations shall not face the cargo connection location of the unloading arrangements. They shall be located on the outboard side of the superstructure or deckhouse at a distance of at least 4 per cent of the length of the ship unit, but not less than 3 m from the end of the superstructure or deckhouse facing the cargo connection location of the unloading arrangements. This distance need not exceed 5 m.

- *.1* Windows and sidescuttles facing the connection location of the shuttle tanker and on the sides of the superstructure or deckhouse within the distance mentioned above shall be of the fixed (non-opening) type.
- *.2* In addition, during the use of the unloading arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side should be kept closed.

3.8.4 Deck openings and air inlets and outlets to spaces within distances of 10 m from the cargo shore connection location shall be kept closed during the use of the unloading arrangements.

3.8.5 Fire-fighting arrangements for the unloading areas shall generally be in accordance with 11.3.1.4 and 11.4. However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy. Full details of the proposals are to be submitted for consideration.

3.8.6 Means of communication between the cargo control station and the connection location of the shuttle tanker shall be provided and where applicable certified for use in hazardous areas.

LR 3.8.1 Hull, hull weather deck and liquefied gas offloading arrangements shall generally be treated for the purpose of fire containment according to SOLAS Regulation II-2/9.2.4 and for fire mitigation according to Pt 11, Ch 11. However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy.

4.1 Definitions

4.1.1 **Cold spot**. A cold spot is a part of the hull or thermal insulation surface where a localised temperature decrease occurs under loaded condition with respect to the allowable minimum temperature of the hull or of its adjacent hull structure, or to design capabilities of cargo pressure/ temperature control systems required in Chapter 7.

4.1.2 **Design vapour pressure**. The design vapour pressure 'P_o' is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

4.1.3 **Design temperature**. The design temperature for selection of materials is the minimum temperature at which cargo may be loaded or stored in the cargo tanks.

4.1.4 **Independent tanks** are self-supporting; they do not form part of the hull of the ship unit and are not essential to the hull strength. There are three categories of independent tank, which are referred to in 4.21, 4.22 and 4.23.

4.1.5 **Membrane tanks** are non-self-supporting tanks that consist of a thin liquid and gas tight layer (membrane) supported through insulation by the adjacent hull structure. Membrane tanks are covered in 4.24.

4.1.6 **Integral tanks** are tanks that form a structural part of the hull and are influenced in the same manner by the loads that stress the adjacent hull structure. Integral tanks are covered in 4.25.

4.1.7 **Semi-membrane tanks** are non-self-supporting tanks in the loaded condition and consist of a layer, parts of which are supported through insulation by the adjacent hull structure. Semi-membrane tanks are covered in 4.26.

4.1.8 In addition to the definitions in 1.2, the definitions given in this Chapter shall apply throughout this Part.

4.2 Application

Unless otherwise specified in part E, the requirements of parts A to D shall apply to all types of tanks, including those covered in part F.

Part A Cargo containment

4.3 Functional requirements

LR 4.3.1 Details of the proposed design of cargo containment systems are to be submitted for consideration, and it is recommended this is done at as early a stage as possible. For a description of LR's system of approval, refer to the Marine Survey Guidance System. *See also* LR 1.3.

4.3.1 The design life of the cargo containment system shall not be less than the design life of the ship unit.

LR 4.3.2 Cargo containment systems shall be designed with site-specific environmental loads for the proposed area of operation. The cargo containment system shall also be designed for all transit conditions as applicable to the operational philosophy of the unit; this includes delivery voyages and sail-away disconnect conditions.

4.3.3 Cargo containment systems shall be designed with suitable safety margins:

.1 to withstand, in the intact condition, the environmental conditions anticipated for the cargo containment system's design life and the loading conditions appropriate for them, which include loads derived for the following scenarios: on-site operation, inspection/maintenance, transit/disconnect and accidental. The most onerous loading conditions are to be considered.

.2 that are appropriate for uncertainties in loads, structural modelling, fatigue, corrosion, thermal effects, material variability, ageing and construction tolerances.

4.3.4 The cargo containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling, and fatigue. The specific design conditions that should be considered for the design of each cargo containment system are given in 4.21 to 4.26. There are three main categories of design conditions:

.1 **Ultimate design conditions** – The cargo containment system structure and its structural components shall withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design shall take into account proper combinations of the following loads:

- Internal pressure.
- External pressure.
- Dynamic loads due to the motion of the ship unit.
- Thermal loads.
- Sloshing loads.
- Loads corresponding to deflections of the ship unit.
- Tank and cargo weight with the corresponding reaction in way of supports.
- Insulation weight.
- Loads in way of towers and other attachments.
- Test loads.
- 10 000 year return period loading (this requirement may be waived where it can be proven that it is not appropriate, on a site-specific basis).

.2 **Fatigue design conditions** – The cargo containment system structure and its structural components shall not fail under accumulated cyclic loading.

.3 **Accident design conditions** – The cargo containment system shall provide the indicated response to each of the following accident conditions (accidental or abnormal events), addressed in this Part:

- Fire – The cargo containment systems shall sustain without rupture the rise in internal pressure specified in 8.4.1 under the fire scenarios envisaged therein.
- Flooded compartment causing buoyancy on tank – The anti-flotation arrangements shall sustain the upward force, specified in 4.15.1 and there should be no endangering plastic deformation to the hull.

4.3.5 Measures shall be applied to ensure that scantlings required meet the structural strength provisions and will be maintained throughout the design life. Measures include, but are not limited to, material selection, coatings, corrosion additions, cathodic protection and inerting.
Corrosion allowance need not be required in addition to the thickness resulting from the structural analysis. However, where there is no environmental control, such as inerting around the cargo tank, or where the cargo is of a corrosive nature, LR may require a suitable corrosion allowance.

LR 4.3.3 In areas where excessive corrosion might be expected, a corrosion addition may be required if means of protection are not installed.

4.3.6 An inspection/survey plan for the cargo containment system shall be developed and approved at the time of build. The inspection/survey plan shall identify areas that need inspection during surveys throughout the cargo containment system's life and in particular all necessary in-service survey and maintenance that was assumed when selecting cargo containment system design parameters. Cargo containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Cargo containment systems, including all associated internal equipment shall be designed and built to ensure safety during operations, inspection and maintenance (*see* 3.5).

4.4 Cargo containment safety principles

4.4.1 The containment systems shall be provided with a full secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the structure of the ship unit to an unsafe level.

4.4.2 However, the size and configuration or arrangement of the secondary barrier can be reduced where an equivalent level of safety can be demonstrated in accordance with the requirements of 4.4.3 to 4.4.5 as applicable.

4.4.3 Cargo containment systems for which the probability for structural failures to develop into a critical state has been determined to be extremely low, but where the possibility of leakages through the primary barrier cannot be excluded, shall be equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages.
The arrangements shall comply with the following requirements:

.1 Failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) shall have a sufficiently long development time for remedial actions to be taken.

.2 Failure developments that cannot be safely detected before reaching a critical state shall have a predicted development time that is much longer than the expected lifetime of the tank.

4.4.4 No secondary barrier is required for cargo containment systems, e.g. Type C independent tanks, where the probability for structural failures and leakages through the primary barrier is extremely low and can be neglected.

4.4.5 No secondary barrier is required where the cargo temperature at atmospheric pressure is at or above –10°C.

4.5 Secondary barriers in relation to tank types

Secondary barriers in relation to the tank types defined in 4.21 to 4.26 shall be provided in accordance with Table 4.5.1.

Table 4.5.1 Secondary barriers in relation to tank types

Cargo temperature at atmospheric pressure	–10°C and above	Below –10°C down to –55°C	Below –55°C
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Integral		Tank type not normally allowed, *see* Note 1	
Membrane		Complete secondary barrier	
Semi-membrane		Complete secondary barrier *see* Note 2	
Independent			
Type A		Complete secondary barrier	
Type B		Partial secondary barrier	
Type C		No secondary barrier required	

NOTES
1. A complete secondary barrier should normally be required if cargoes with a temperature at atmospheric pressure below –10°C are permitted in accordance with 4.25.1.
2. In the case of semi-membrane tanks that comply in all respects with the requirements applicable to Type B independent tanks, except for the manner of support, the Administration may, after special consideration, accept a partial secondary barrier.

4.6 Design of secondary barriers

4.6.1 Where the cargo temperature at atmospheric pressure is not below –55°C, the hull structure may act as a secondary barrier based on the following:

.1 the hull material shall be suitable for the cargo temperature at atmospheric pressure as required by 4.19.1.4; and

.2 the design shall be such that this temperature will not result in unacceptable hull stresses.

4.6.2 The design of the secondary barrier shall be such that:

.1 it is capable of containing any envisaged leakage of liquid cargo for a period of 15 days, unless different project-specific requirements apply, taking into account the load spectrum referred to in 4.18.2.6. Project-specific requirements are to be submitted for consideration.

.2 physical, mechanical, or operational events within the cargo tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa.

.3 failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers.

.4 it is capable of being periodically checked for its effectiveness by means acceptable to LR of a visual inspection or a pressure/vacuum test or other suitable means carried out according to a documented procedure agreed with LR.

LR 4.6.1 Proposals for the periodical examination of the secondary barrier are to be submitted for consideration.

.5 The methods required in 4.6.2.4 shall be approved by LR and shall include, where applicable to the test procedure:

1. Details on the size of defect acceptable and the location within the secondary barrier, before its liquid tight effectiveness is compromised.
2. Accuracy and range of values of the proposed method for detecting defects in 4.6.2.5.1.
3. Scaling factors to be used if full scale model testing is not undertaken.
4. Effects of thermal and mechanical cyclic loading on the effectiveness of the proposed test.

.6 The secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°.

4.7 Partial secondary barriers and primary barrier small leak protection system

4.7.1 Partial secondary barriers shall be used with a small leak protection system and meet all the requirements in 4.6.2. The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquid cargo down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

4.7.2 The capacity of the partial secondary barrier shall be determined, based on the cargo leakage corresponding to the extent of failure resulting from the load spectrum referred to in 4.18.2.6, after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.

4.7.3 The required liquid leakage detection may be by means of liquid sensors, or by an effective use of pressure, temperature or gas detection systems, or any combination thereof.

4.8 Supporting arrangements

4.8.1 The cargo tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in 4.12 to 4.15, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

LR 4.8.1 Tank supporting arrangements are generally to be located in way of the primary support structure of the tank and the hull of the ship unit. Steel seatings are to be arranged, where possible, on both the inner bottom and underside of the cargo tank so as to ensure an effective distribution of the transmitted load and reactions into the cargo tanks and double bottom structure.

LR 4.8.2 The strength of supporting arrangements is to be verified by direct calculation.

4.8.2 Anti-flotation arrangements shall be provided for independent tanks and be capable of withstanding the loads defined in 4.15.1 without plastic deformation likely to endanger the hull structure.

4.8.3 Supports and supporting arrangements shall withstand the loads defined in 4.13.8 and 4.15, but these loads need not be combined with each other or with wave-induced loads.

LR 4.8.3 An adequate clearance is to be provided between the anti-flotation chocks and the hull of the ship unit in all operational conditions.

LR 4.8.4 The effects on the supporting arrangements of the 10 000 year return period wave loading are to be considered as follows:

- Resulting acceleration loadings.
- Hull interaction loadings.

Calculations and analyses are to be performed to show that there would be no gross failure of the supporting arrangements in this event as prescribed above for each tank type.

4.9 Associated structure and equipment

4.9.1 Cargo containment systems are to be designed for the loads imposed by associated structure and equipment. This includes pump towers, cargo domes, cargo pumps and piping, stripping pumps and piping, inert gas piping, access hatches, ladders, piping penetrations, liquid level gauges, independent level alarm gauges, spray nozzles, and instrumentation systems (such as pressure, temperature and strain gauges).

4.10 Thermal insulation

4.10.1 Thermal insulation shall be provided as required to protect the hull from temperatures below those allowable (*see* 4.19.1) and to limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in Chapter 7.

4.10.2 In determining the insulation performance, due regard should be paid to the amount of the acceptable boil-off in association with the liquefaction or reliquefaction plant on board, gas consumers if present or other temperature control system.

Part B Design loads

4.11 General

This Section defines the design loads to be considered with regard to the requirements in 4.16, 4.17 and 4.18. This includes:

- Load categories (permanent, functional, environmental and accidental) and the description of the loads.

The extent to which these loads should be considered depends on the type of tank, and is more fully detailed in the following paragraphs.
Tanks, together with their supporting structure and other fixtures, that shall be designed taking into account relevant combinations of the loads described below.

4.12 Permanent loads

4.12.1 **Gravity loads**
The weight of tank, thermal insulation, loads caused by towers and other attachments.

4.12.2 **Permanent external loads**
Gravity loads of structures and equipment acting externally on the tank.

4.13 Functional loads

Loads arising from the operational use of the tank system shall be classified as functional loads.
All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, shall be considered.
As a minimum, the effects from the following criteria, as applicable, shall be considered when establishing functional loads:

- Internal pressure.
- External pressure.
- Thermally induced loads.
- Vibration.
- Interaction loads.
- Loads associated with construction and installation.
- Test loads.
- Static heel loads.
- Weight of cargo.

4.13.1 **Internal pressure**

.1 In all cases, including 4.13.1.2, P_o shall not be less than MARVS.

.2 For cargo tanks where there is no temperature control and where the pressure of the cargo is dictated only by the ambient temperature, P_o shall not be less than the gauge vapour pressure of the cargo at a temperature equal to the maximum daily mean ambient air temperature for the unit's proposed area of operation based on the 100 year average return period. The ambient temperature is to be rounded up to the nearest degree Celsius, and not to be taken as less than 45°C unless agreed by LR.

.3 Subject to special consideration by the Administration and to the limitations given in 4.21 to 4.26, for the various tank types, a vapour pressure P_h higher than P_o may be accepted for site-specific conditions where dynamic loads are reduced.

.4 The internal pressure P_{eq} results from the vapour pressure P_o or P_h plus the maximum associated dynamic liquid pressure P_{gd}, but not including the effects of liquid sloshing loads. Guidance formulae for associated dynamic liquid pressure P_{gd} are given in 4.27.1.

4.13.2 **External pressure**

External design pressure loads shall be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

4.13.3 **Thermally induced loads**

Transient thermally induced loads during cooling down periods shall be considered for tanks intended for cargo temperatures below –55°C.
Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses. *See* 7.2.

4.13.4 **Vibration**

The potentially damaging effects of vibration on the cargo containment system shall be considered.

4.13.5 **Interaction loads**

The static component of loads resulting from interaction between cargo containment system and the hull structure, as well as loads from associated structure and equipment, shall be considered.

4.13.6 **Loads associated with construction and installation**

Loads or conditions associated with construction and installation shall be considered, e.g. lifting.

4.13.7 **Test loads**

Account shall be taken of the loads corresponding to the testing of the cargo containment system referred to in 4.21 to 4.26.

4.13.8 **Static heel loads**

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30° shall be considered.

LR 4.13.1 10 000 year return period loading

The effects on the containment system of the 10 000 year return period wave loading are to be considered.

4.13.9 **Other loads**

Any other loads not specifically addressed, which could have an effect on the cargo containment system, shall be taken into account.

4.14 Environmental loads

Environmental loads are defined as those loads on the cargo containment system that are caused by the surrounding environment and that are not otherwise classified as a permanent, functional or accidental load.

4.14.1 **Loads due to ship motion**

The determination of dynamic loads shall take into account the long-term distribution of ship motion in irregular seas, which the ship unit will experience during its operating life. Account may be taken of the reduction in dynamic loads due to heading control.
The motions of the ship unit shall include surge, sway, heave, roll, pitch and yaw. The accelerations, derived from site-specific wave data and the heading analysis, acting on tanks, shall be estimated at their centre of gravity and include the following components:

- vertical acceleration: motion accelerations of heave, pitch and possibly roll (normal to the base of the ship unit);
- transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll;
- longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

Methods to predict accelerations due to ship motion shall be proposed and approved by LR.
Guidance formulae for acceleration components are given in 4.27.2.

LR 4.14.1 The determination of the dynamic loads may be based on the results of model tests and/or by suitable direct calculation methods of the actual loads on the cargo containment system at the site-specific location, taking into account the following service-related factors:
(a) site-specific environmental loads including relevant non-linear effects;
(b) mooring system and riser loads;
(c) unit orientation and wave loading directions;
(d) long-term service effects at a fixed location;
(e) range of tank loading conditions, including empty tanks required for on-station surveys;
(f) potential relocations if applicable.
The actual form and weight distribution of the unit and the longitudinal and transverse locations of the tanks are to be taken into account.

4.14.2 **Dynamic interaction loads**
Account shall be taken of the dynamic component of loads resulting from interaction between cargo containment systems and the hull structure, including loads from associated structures and equipment.

4.14.3 **Sloshing loads**
The sloshing loads on a cargo containment system and internal components, induced by any of the site-specific motions referred to in 4.14.1, shall be evaluated based on allowable filling levels.
When significant sloshing-induced loads are expected to be present, special tests and calculations shall be required covering the full range of intended filling levels.

LR 4.14.2 Where loading conditions are proposed, including one or more partially filled tanks, calculations or model tests will be required to show that the resulting loads and pressure are within acceptable limits for the scantlings of the tanks. Additionally, investigations should be made to ensure that the internal structure, equipment and pipework exposed to fluid motion are of adequate strength.

LR 4.14.3 If the liquefied gas storage tanks are to have no filling restrictions, the capacity of the cargo containment system to resist the greatest predicted sloshing pressures is to be assessed for fill heights representative of all filling levels in accordance with this Section.
If filling restrictions are contemplated, the capacity of the cargo containment system to resist sloshing predicted pressures needs to be assessed only for fill heights representative of the permitted filling ranges. In this case, the filling restrictions are to be stated in the approved Loading Manual.

4.14.4 **Snow and ice loads**
Snow and icing shall be considered, if relevant.

4.14.5 **Loads due to operation in ice conditions**
Loads due to operation in ice conditions shall be considered for units intended for such service. The effects on the containment system due to additional topside weight as a result of ice accretion, and ice collisions against the hull should be considered, *see also* Pt 3, Ch 6.

4.15 Accidental loads

Accidental loads are defined as loads that are imposed on a cargo containment system and its supporting arrangements under abnormal and unplanned conditions.

4.15.1 **Loads due to flooding**
For independent tanks, loads caused by the buoyancy of an empty tank in a hold space, flooded to the summer load draught, shall be considered in the design of the anti-flotation chocks and the supporting hull structure.

Part C Structural integrity

4.16 General

The structural design shall ensure that tanks have an adequate capacity to sustain all relevant loads with an adequate margin of safety. This should take into account the possibility of plastic deformation, buckling, fatigue and loss of liquid and gas tightness.
The structural integrity of cargo containment systems can be demonstrated by compliance with 4.21 to 4.26, as appropriate for the cargo containment system type.

4.17 Structural analyses

4.17.1 **Analysis**
The design analyses shall be based on accepted principles of statics, dynamics and strength of materials.
Simplified methods or simplified analyses may be used to calculate the load effects, provided that they are conservative. Model tests may be used in combination with, or instead of, theoretical calculations. In cases where theoretical methods are inadequate, model or full-scale tests may be required.
When determining responses to dynamic loads, the dynamic effect shall be taken into account where it may affect structural integrity.

LR 4.17.1 Where direct calculation procedures are adopted, the assumptions made and other details of the calculations are to be submitted.

4.17.2 **Load scenarios**
For each location or part of the cargo containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously shall be considered.
The most onerous load scenarios for all relevant phases of the life-cycle shall be considered. Loads during construction/handling, installation, on-site operation, inspection/maintenance including testing and in transit/disconnect conditions shall be considered, as applicable.

4.17.3 When the static and dynamic stresses are calculated separately and unless other methods of calculation are justified, the total stresses shall be calculated according to:

$$\sigma_x = \sigma_{x.st} \pm \sqrt{\Sigma(\sigma_{x.dyn})^2}$$

$$\sigma_y = \sigma_{y.st} \pm \sqrt{\Sigma(\sigma_{y.dyn})^2}$$

$$\sigma_z = \sigma_{z.st} \pm \sqrt{\Sigma(\sigma_{z.dyn})^2}$$

$$\tau_{xy} = \tau_{xy.st} \pm \sqrt{\Sigma(\tau_{xy.dyn})^2}$$

$$\tau_{xz} = \tau_{xz.st} \pm \sqrt{\Sigma(\tau_{xz.dyn})^2}$$

$$\tau_{yz} = \tau_{yz.st} \pm \sqrt{\Sigma(\tau_{yz.dyn})^2}$$

where:

$\sigma_{x.st}$, $\sigma_{y.st}$, $\sigma_{z.st}$, $\tau_{xy.st}$, $\tau_{xz.st}$ and $\tau_{yz.st}$ = static stresses

$\sigma_{x.dyn}$, $\sigma_{y.dyn}$, $\sigma_{z.dyn}$, $\tau_{xy.dyn}$, $\tau_{xz.dyn}$ and $\tau_{yz.dyn}$ = dynamic stresses

Each shall be determined separately from acceleration components and hull strain components due to deflection and torsion.

4.18 Design conditions

All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this Chapter, and the load scenarios are covered by 4.17.2.

4.18.1 **Ultimate design condition**

Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, or by simplified linear elastic analysis.

4.18.1.1 Plastic deformation and buckling shall be considered.

4.18.1.2 Analysis shall be based on characteristic load values as follows:

Permanent Loads	Expected Values
Functional Loads	Specified Values
Environmental Loads	For wave loads; most probable largest load encountered by the ship unit during its operating life.

4.18.1.3 For the purpose of ultimate strength assessment the following material parameters apply:

.1 R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress-strain curve does not show a defined yield stress, the 0,2 per cent proof stress applies.

R_m = specified minimum tensile strength at room temperature (N/mm^2).

NOTE

For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloys, the respective R_e and R_m of the welds, after any applied heat treatment, shall be used. In such cases the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials shall not be incorporated in cargo containment systems.

.2 The above properties shall correspond to the minimum specified mechanical properties of the material, including the weld metal in the as-fabricated condition. Subject to special consideration by LR, account may be taken of the enhanced yield stress and tensile strength at low temperature.

4.18.1.4 The equivalent stress σ_c (von Mises, Huber) shall be determined by:

$$\sigma_c = \sqrt{\sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3(\tau_{xy}{}^2 + \tau_{xz}{}^2 + \tau_{yz}{}^2)}$$

where

σ_x = total normal stress in x-direction
σ_y = total normal stress in y-direction
σ_z = total normal stress in z-direction
τ_{xy} = total shear stress in x-y plane.
τ_{xz} = total shear stress in x-z plane
τ_{yz} = total shear stress in y-z plane.

4.18.1.5 Allowable stresses for materials other than those covered by Chapter 6 shall be subject to approval by LR in each case.

LR 4.18.1 Details of the proposals are to be submitted for consideration.

4.18.1.6 Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

LR 4.18.2 The stresses resulting from the 10 000 year return period wave loading are not to exceed yield, or a higher stress level, provided permanent deformation can be permitted.

4.18.2 **Fatigue design condition**

4.18.2.1 The fatigue design condition is the design condition with respect to accumulated cyclic loading.

4.18.2.2 Where a fatigue analysis is required, the maximum allowable cumulative fatigue damage ratio is to be less than or equal to 0,5, but is to be no greater than 0,33 for any parts of the supporting structure which are not accessible for inspection during the service life of the unit.
The fatigue assessment of the cargo containment system is to be verified in accordance with the ShipRight Procedure for Ship Units.
The loading/unloading history is to be consistent with the intended operation of the ship unit. Plastic strain is to be accounted for in the low cycle region. Loading and unloading cycles are to include a complete pressure and thermal cycle.
The fatigue damage shall be based on the design life of the tank but not less than 10^8 wave encounters.

4.18.2.3 Where required, the cargo containment system shall be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the cargo containment system. Consideration shall be given to various filling conditions.

4.18.2.4 Design S-N curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.
The S-N curves shall be based on a 97,6 per cent probability of survival corresponding to the mean minus two standard deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable C_w values specified in 4.18.2.7 to 4.18.2.9.

4.18.2.5 Analysis shall be based on characteristic load values as follows:

Permanent loads	Expected values
Functional loads	Specified values or specified history
Environmental loads	Expected load history, but not less than 10^8 cycles

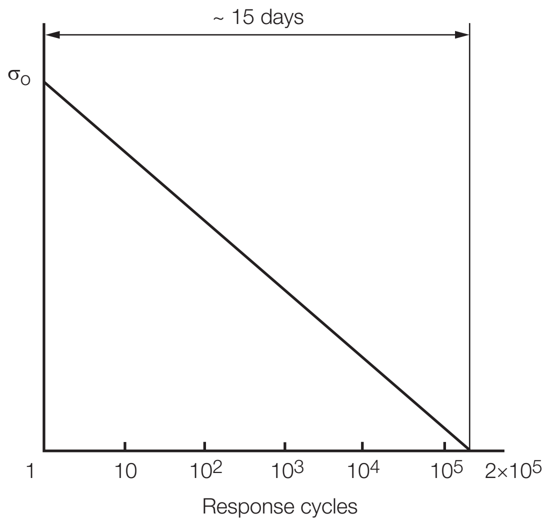
If simplified dynamic loading spectra are used for the estimation of the fatigue life, those shall be specially considered by LR.

4.18.2.6 Where the size of the secondary barrier is reduced, as is provided for in 4.4.3, fracture mechanics analyses of fatigue crack growth shall be carried out for the primary barrier to determine:

- Crack propagation paths in the structure.
- Crack growth rate.
- The time required for a crack to propagate to cause a leakage from the tank.
- The size and shape of through-thickness cracks.
- The time required for detectable cracks to reach a critical state.

The fracture mechanics are in general based on crack growth data taken as a mean value plus two standard deviations of the test data.
In analysing crack propagation the largest initial crack or equivalent defect not detectable by the inspection method applied shall be assumed, taking into account the allowable non-destructive testing and visual inspection criterion as applicable.

For the crack propagation analysis under the condition specified in 4.18.2.7, the simplified load distribution and sequence over a period of 15 days may be used, unless different project-specific requirements apply. Project-specific requirements are to be submitted for consideration. Such distributions may be obtained as indicated in Fig. 4.1. Load distribution and sequence for longer periods, such as in 4.18.2.8 and 4.18.2.9 shall be approved by LR.
The arrangements shall comply with 4.18.2.7 to 4.18.2.9 as applicable:



σ_o = most probable maximum stress over the life cycle of the ship unit
Response cycle scale is logarithmic; the value of 2×10^5 is given as an example of estimate

Fig. 4.1 Simplified load distribution

4.18.2.7 For failures that can be reliably detected by means of leakage detection;

- C_w shall be less than or equal to 0,5.
- The predicted remaining failure development time, from the point of detection of leakage until reaching a critical state, shall not be less than 15 days unless different project-specific requirements apply. Project-specific requirements are to be submitted for consideration.

4.18.2.8 For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections;

- C_w shall be less than or equal to 0,5.
- Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three times the inspection interval.

4.18.2.9 In particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria should be applied as a minimum;

- C_W shall be less than or equal to 0,1.
- The predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three times the lifetime of the tank.

4.18.3 **Accident design condition**

The accident design condition is a design condition for accidental loads with extremely low probability of occurrence. Analysis shall be based on the characteristic values as follows:

Permanent loads	Expected values
Functional loads	Specified values
Environmental loads	Specified values
Accidental loads	Specified values or expected values

Loads mentioned in 4.13.8 and 4.15 need not be combined with each other or with wave induced loads.

Part D Materials and construction

4.19 Materials

LR 4.19.1 The specification and plans of the cargo containment system including the insulation are to be submitted for approval. The materials used are to be approved by LR, *see* Chapter 6. For the plans to be submitted, *see* LR 1.6.

4.19.1 **Materials forming the structure of the ship unit**

4.19.1.1 To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types when the cargo temperature is below –10°C. The following assumptions should be made in this calculation:

.1 The primary barrier of all tanks shall be assumed to be at the cargo temperature.

.2 In addition to item 1, where a complete or partial secondary barrier is required it shall be assumed to be at the cargo temperature at atmospheric pressure for any one tank only.

.3 The ambient temperatures for air and sea-water are to be taken at their lowest daily mean temperatures for the unit's proposed area of operation based on the 100 year average return period. The ambient temperatures are to be rounded down to the nearest degree Celsius. The ambient temperatures are not to be taken as greater than 5°C for air and 0°C for sea-water unless agreed by LR.

.4 Still air and sea water conditions shall be assumed, i.e. no adjustment for forced convection.

.5 Degradation of the thermal insulation properties over the life of the ship unit due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations as defined in 4.19.3.6 and 4.19.3.7 shall be assumed.

.6 The cooling effect of the rising boil-off vapour from the leaked cargo should be taken into account where applicable.

.7 No credit shall be given for any means of heating, except as described in 4.19.1.5.

.8 For members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

LR 4.19.2 When heat transmission studies are carried out, the heat balance method is acceptable to LR.

4.19.1.2 The shell and deck plating of the ship unit and all stiffeners attached thereto shall be in accordance with the requirements of Part 10 and this Part. If the calculated temperature of the material in the design condition is below –5°C due to the influence of the cargo temperature and ambient sea and air temperatures, the material shall be in accordance with Table 6.5. The ambient sea and air temperatures are to be determined as defined in 4.19.1.1.3.

4.19.1.3 The materials of all other hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of cargo temperature and ambient sea and air temperatures, and that do not form the secondary barrier, shall also be in accordance with Table 6.5. This includes hull structure supporting the cargo tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members. The ambient sea and air temperatures are to be determined as defined in 4.19.1.1.3.

4.19.1.4 The hull material forming the secondary barrier shall be in accordance with Table 6.2. Where the secondary barrier is formed by the deck or side shell plating, the material grade required by Table 6.2 shall be carried into the adjacent deck or side shell plating, where applicable, to a suitable extent.

4.19.1.5 Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in Table 6.5. In the calculations required in 4.19.1.1, credit for such heating may be taken in accordance with the following:

.1 for any transverse hull structure;

.2 for longitudinal hull structure referred to in 4.19.1.2 and 4.19.1.3 where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of +5°C for air and 0°C for sea-water with no credit taken in the calculations for heating; and

.3 as an alternative to 4.19.1.5.2, for longitudinal bulkhead between cargo tanks, credit may be taken for heating provided the material remains suitable for a minimum design temperature of –30°C, or a temperature 30°C lower than that determined by 4.19.1.1 with the heating considered, whichever is less. In this case, the longitudinal strength of the ship unit shall comply with SOLAS Regulation II-1/3-1 for both when those bulkhead(s) are considered effective and not.

4.19.1.6 The means of heating referred to in 4.19.1.5 shall comply with the following requirements:

.1 the heating system shall be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to not less than 100 per cent of the theoretical heat requirement;

.2 the heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with 4.19.1.5.1 shall be supplied from the emergency source of electrical power; and

.3 the design and construction of the heating system shall be included in the approval of the containment system by LR.

LR 4.19.3 Details of the proposed heating system are to be submitted.

4.19.2 **Materials of primary and secondary barriers**

4.19.2.1 Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with Table 6.1, 6.2 or 6.3.

4.19.2.2 Materials, either non-metallic or metallic but not covered by Tables 6.1, 6.2 and 6.3, used in the primary and secondary barriers may be approved by LR considering the design loads that they may be subjected to, their properties and their intended use.

4.19.2.3 Where non-metallic materials, including composites, are used for or incorporated in the primary or secondary barriers, they shall be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:

- compatibility with the cargoes;
- solubility in cargo;
- absorption of cargo;
- ageing;
- density;
- mechanical properties;
- thermal expansion and contraction;
- abrasion;
- cohesion;
- resistance to vibrations;
- resistance to fire and flame spread;
- resistance to fatigue failure and crack propagation;
- influence of water;
- resistance to cargo pressure.

4.19.2.4 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than –196°C.

4.19.2.5 Where non-metallic materials, including composites, are used for the primary and secondary barriers, the joining processes shall also be tested as described above.

4.19.2.5.1 Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in Appendix 1.

4.19.2.6 Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire retardant barrier.

4.19.3 **Thermal insulation and other materials used in cargo containment systems**

4.19.3.1 Load-bearing thermal insulation and other materials used in cargo containment systems shall be suitable for the design loads.

4.19.3.2 Thermal insulation and other materials used in cargo containment systems shall have the following properties, as applicable, to ensure that they are adequate for the intended service:

- compatibility with the cargoes;
- solubility in the cargo;
- absorption of the cargo;
- shrinkage;
- ageing;
- closed cell content;
- density;
- mechanical properties, to the extent that they are subjected to cargo and other loading effects, thermal expansion and contraction;
- abrasion;
- cohesion;
- thermal conductivity;
- resistance to vibrations;
- resistance to fire and flame spread;
- resistance to fatigue failure and crack propagation.

LR 4.19.4 In addition to the requirements given in 4.19.3.2, fatigue and crack propagation properties for insulation in membrane systems are also to be submitted. Insulation materials are to be approved by LR. Where applicable, these requirements also apply to any adhesive, sealers, vapour barriers, coatings or similar products used in the insulation system, any material used to give strength to the insulation system, components used to hold the insulation in place and any non-metallic membrane materials. Such products are to be compatible with the insulation.

4.19.3.3 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than –196°C.

4.19.3.4 Due to location or environmental conditions, thermal insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, and in way of tank cover penetrations, it shall have suitable fire resistance properties in accordance with a recognised Standard acceptable to LR or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal.

LR 4.19.5 Where the insulation is located on or immediately adjacent to the open deck, or is in an interbarrier or hold space not kept inerted in accordance with 9.2.1, it is to have suitable fire resistance properties. If the insulation is located in an inerted atmosphere and is separated from the open deck by a void space or ballast tank, then insulation having fire resisting properties is not required.
In addition, all insulation is to be covered with a covering having low flame spread characteristics.
An efficient vapour barrier (seal) is to be provided on the outer surface of the insulation. The vapour barrier is to be of an approved type.

4.19.3.5 Thermal insulation that does not meet recognised Standards acceptable to LR for fire resistance may be used in hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame spread characteristics and that forms an efficient approved vapour seal.

4.19.3.6 Testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples.

4.19.3.7 Where powder or granulated thermal insulation is used, measures shall be taken to reduce compaction in service, for example due to vibrations, and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the cargo containment system.

LR 4.19.6 Particular attention is to be paid to the cleaning of the steelwork prior to the application of the insulation. Where insulation is to be foamed or sprayed *in situ*, the minimum steelwork temperature at the time of application is to be indicated in the specification in addition to environmental conditions.

4.20 Construction processes

LR 4.20.1 A construction, testing and inspection (CTI) plan for the installation of the containment system is to be submitted for approval. This plan is to list the following sequentially for each stage of installation, testing and inspection:

(a) The method to be used.
(b) The acceptance criteria.
(c) The form of record to be made.
(d) The involvement of the shipyard, containment system designer where relevant, and LR Surveyor.

The testing and inspection should be commensurate with assumptions made in the design of the containment system, *see* 4.18.2.6. Further detailed documents, which may be cross-referenced by the CTI plan, are to be submitted for approval as applicable.

LR 4.20.2 A detailed quality assurance/quality control (QA/QC) programme shall be applied to ensure the continued conformity of materials in the containment system during installation and service. The quality assurance/quality control programme shall include the procedure for fabrication, storage, handling and preventive actions to guard against exposure of a material to harmful effects. The proposed procedure is to be submitted to LR for consideration. All materials in the containment system are also to be considered and included in the procedure. *See also* Appendix 1,5.

4.20.1 **Weld joint design**

4.20.1.1 All welded joints of the shells of independent tanks shall be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds are also to be designed with full penetration.

LR 4.20.3 Except for the dome-to-shell connections, T-butt welds will not be accepted in the shell.

4.20.1.2 Welding joint details for Type C independent tanks, and for the liquid-tight primary barriers of Type B independent tanks primarily constructed of curved surfaces, shall be as follows:

.1 All longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels. Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure.

.2 The bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to a standard acceptable to LR. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds.

LR 4.20.4 *See also* Pt 5, Ch 10,14 of the Rules for Ships.

4.20.1.3 Where applicable, all the construction processes and testing, except that specified in 4.20.3 shall be done in accordance with the applicable provisions of Chapter 6.

4.20.2 **Design for gluing and other joining processes**
The design of the joint to be glued (or joined by some other process except welding) shall take account of the strength characteristics of the joining process.

4.20.3 **Testing during construction**

4.20.3.1 All cargo tanks and process pressure vessels shall be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with 4.21 to 4.26, as applicable for the tank type.

4.20.3.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 4.20.3.1.

4.20.3.3 Requirements with respect to inspection of secondary barriers shall be decided by LR in each case, taking into account the accessibility of the barrier. *See also* 4.6.2.

4.20.3.4 The Administration may require that, for ship units fitted with novel Type B independent tanks, at least one prototype tank and its supporting structures shall be instrumented with strain gauges or other suitable equipment to confirm stress levels. Similar instrumentation may be required for Type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

4.20.3.5 The overall performance of the cargo containment system shall be verified for compliance with the design parameters during entry into service in accordance with the survey procedure. Records of the performance of the components and equipment, essential to verify the design parameters, shall be maintained and be available to the Administration.

LR 4.20.5 The overall performance of the cargo containment system is to be verified for compliance with the design parameters during initial acceptance cargo trials. The initial trials are to be witnessed by LR's Surveyors, and are to demonstrate that the system is capable of being inerted, cooled, loaded and discharged in a satisfactory manner, and that all safety devices function correctly.
The temperature at which these tests are carried out is to be at or near the minimum cargo temperature. Where a refrigeration plant is fitted, its operation is to be demonstrated to the Surveyors. Records of the plant performance taken during entry into service at minimum temperature are to be submitted. Logs of plant performance are to be maintained for examination by the Surveyors when requested.

4.20.3.6 Heating arrangements, if fitted in accordance with 4.19.1.5 and 4.19.1.6, shall be tested for required heat output and heat distribution.

4.20.3.7 The cargo containment system shall be inspected for cold spots during or immediately following entry into service. Inspection of the integrity of thermal insulation surfaces that can not be visually checked shall be carried out in accordance with recognised Standards.

Part E Tank types

4.21 Type A independent tanks

4.21.1 Design basis

4.21.1.1 Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures. Type A independent tanks are to be designed in accordance with LR 4.21.1 and LR 4.21.2. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_o shall be less than 0,07 MPa.

4.21.1.2 If the cargo temperature at atmospheric pressure is below –10°C, a complete secondary barrier is required as defined in 4.5. The secondary barrier shall be designed in accordance with 4.6.

4.21.2 Structural analysis

4.21.2.1 A structural analysis shall be performed taking into account the internal pressure as indicated in 4.13.1, and the interaction loads with the supporting and keying system as well as a reasonable part of the hull of the ship unit.

4.21.2.2 For parts such as supporting structures not otherwise covered by the requirements of this Part, stresses shall be determined by direct calculations, taking into account the loads referred to in 4.12 to 4.15 as far as applicable, and the deflection of the ship unit in way of supporting structures.

4.20.2.3 The tanks with supports shall be designed for the accidental loads specified in 4.15. These loads need not be combined with each other or with environmental loads.

LR 4.21.1 **Symbols**:

b = width of plating supported, in metres

f = $1,1 - \dfrac{s}{2500S}$ but need not exceed 1,0

f_s = 2,7 for nickel steels and carbon manganese steels
3,9 for austenitic steels and aluminium alloys

h = vertical distance, from the middle of the effective span of stiffener or transverse to the top of the tank, in metres

l = effective span or girder or web, in metres, *see* Pt 3, Ch 3,3.3 of the Rules for Ships

l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3 of the Rules for Ships

l_t, l_s, l_b, l_c are effective spans measured according to Fig. LR 4.1

ρ = maximum density of the cargo, in kg/m^3, at the design temperature

k = higher tensile steel factor, *see* Pt 3, Ch 2,1.2 of the Rules for Ships

t_p = thickness, in mm, of the attached load bearing plating. Where this varies over the effective width of plating, the mean thickness is to be used

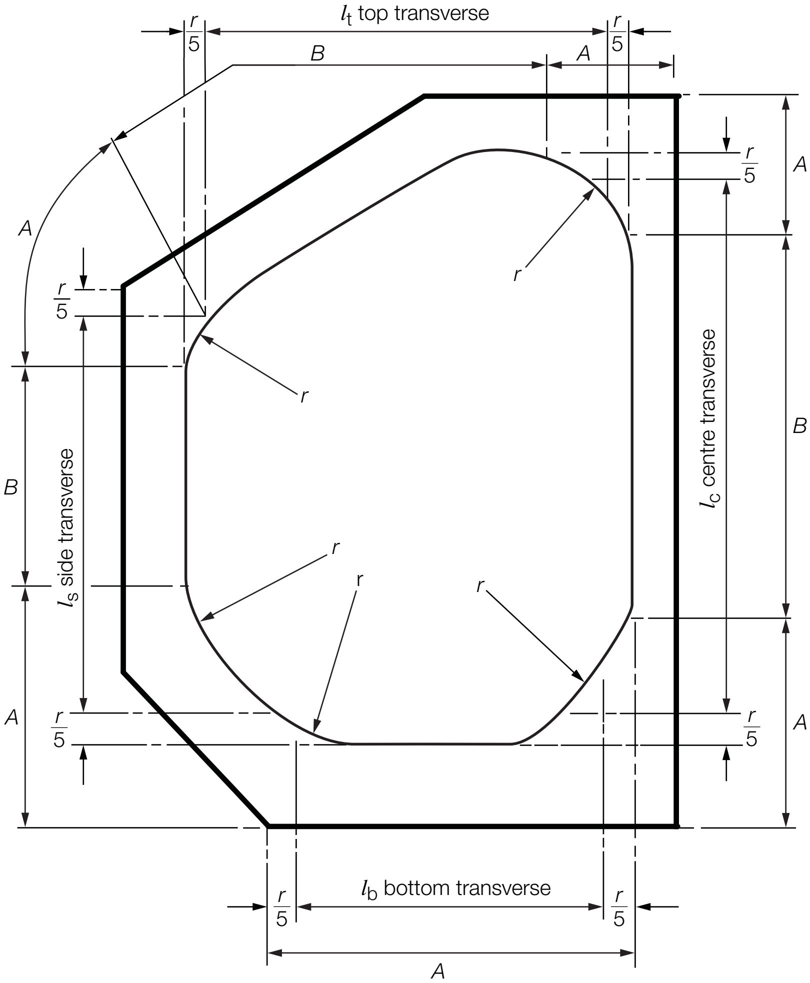
P_{eq} = the internal pressure head, in bar, as derived from 4.13.1.4 and measured at a point on the plate one third of the depth of the plate above its lower edge

s = spacing of bulkhead stiffeners, in mm

S = spacing of primary members, in metres

S_w and s_1 are as defined in Fig. 10.5.1 in Pt 3, Ch 10,5.2 of the Rules for Ships.

The remaining symbols are as defined in Pt 4, Ch 1,9,2 of the Rules for Ships. The lateral and torsional stability of stiffeners should comply with the requirements of Pt 4, Ch 9,5.6 of the Rules for Ships.



NOTE
r should generally be not less than twice the depth of the smaller adjacent web

Fig. LR 4.1 Measurement of spans

LR 4.21.2 The scantlings of Type A independent tanks are to comply with the following:

(a) **Minimum thickness**.
No part of the cargo tank structure is to be less than 7,5 mm in thickness.

(b) **Boundary plating**.
The thickness of plating forming the boundaries of cargo tanks is to be not less than 7,5 mm, nor less than:

$$t = 0{,}011 s\, f \sqrt{P_{eq}\, k} \text{ mm}$$

NOTE
An additional corrosion allowance of 1 mm is to be added to the thickness derived if the cargo is of corrosive nature, *see also* 4.3.5 and LR 4.3.3.

(c) **Rolled or built stiffeners**.
The section modulus of rolled or built stiffeners on plating forming tank boundaries is to be not less than:

$$Z = \frac{P_{eq}\, s\, k\, l_e^2}{f_s\, \gamma\, (\omega_1 + \omega_2 + 2)} \text{ cm}^3.$$

(d) **Transverses**.
The scantlings of transverse members are normally to be derived using direct calculation methods. The structural analysis is to take account of the internal pressure defined in 4.13.1.4 and also those resulting from structural test loading conditions. Proper account is also to be taken of structural model end constraints, shear and axial forces present and any interaction from the double bottom structure through the cargo tank supports.
As an initial estimate, the scantlings of the primary transverses may be taken as:
top transverse

$$Z = 72 P_{eq}\, s\, l_t^2\, k \text{ cm}^3$$

topside transverse

$$Z = 52 P_{eq}\, s\, l_t^2\, k \text{ cm}^3$$

side transverse

$$Z = 56 P_{eq}\, s\, l_s^2\, k \text{ cm}^3$$

bottom transverse

$$Z = 56 P_{eq}\, s\, l_b^2\, k \text{ cm}^3$$

centreline bulkhead transverse

$$Z = 40 P_{eq}\, s\, l_c^2\, k \text{ cm}^3$$

The depth of the bottom transverse web is generally to be not less than $l_b/4$.
Web stiffening is to be in accordance with Pt 4, Ch 9,10.5 of the Rules for Ships with the application of the stiffening requirements as shown in Fig. LR 4.1.

(e) **Tank end webs and girders**.
The section modulus of vertical webs and horizontal girders is to be not less than:

$$Z = 85 P_{eq}\, b\, l^2\, k \text{ cm}^3.$$

(f) **Internal bulkheads (perforated)**.
The thickness of plating is to be not less than 7,5 mm, but may require to be increased at the tank boundaries in regions of high local loading.
The section modulus of stiffeners, girders and webs is to be in accordance with Pt 4, Ch 9,8 and Ch 9,9.8 of the Rules for Ships.

(g) **Internal bulkheads (non-perforated)**.
Where a bulkhead may be subjected to an internal pressure head, P_{eq}, resulting from loading on one side only, the scantlings of plating, stiffeners and primary members are to be determined from (b), (c) and (d).
Where no such loading condition is envisaged, the scantlings may be derived as follows:
The thickness of plating is to be not less than would be required for the tank boundary plating at the corresponding tank depth and stiffener spacing, reduced by 0,5 mm. The section modulus of stiffeners and transverses is to be derived from (c) or (d), respectively, but P_{eq} need not exceed:

$$\left(\frac{t_p - 1{,}0}{0{,}01265 s\, f \sqrt{k}}\right)^2 \text{ bar}$$

(h) **Tank crown structure**.
Where the minimum thickness of tank boundary plating (7,5 mm) has been adopted, the section modulus of associated stiffeners and transverses are to be derived as above, but P_{eq} is to be not less than that equivalent to the minimum thickness, that is:

$$P_{eq\ min} = \left(\frac{6{,}5}{0{,}01265 s\, f \sqrt{k}}\right)^2 \text{ bar}$$

The tank crown plating and stiffeners are also to be suitable for a head equivalent to the tank test air pressure where the tank is to be hydro-pneumatically tested.

(j) **Connection of stiffeners to primary supporting members**.
In assessing the arrangement at intersections of continuous secondary and primary members, the requirements of Pt 3, Ch 10,5.2 are to be complied with using the requirements for 'other ship types'. The total load, P, in kN, is to be derived using the internal pressure head, P_{eq}, in bar as given by 4.13.1.4 and the following formulae:

(i) In general:

$$P = 100\,(S_w - 0{,}5 s_1) s_1\, P_{eq} \text{ kN}$$

(ii) For wash bulkheads:

$$P = 120\,(S_w - 0{,}5 s_1) s_1\, P_{eq} \text{ kN.}$$

4.21.3 Ultimate design condition

4.21.3.1 For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, shall not exceed the lower of $R_m/2{,}66$ or $R_e/1{,}33$ for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where R_m and R_e are defined in 4.18.1.3.
However, if detailed calculations are carried out for the primary members, the equivalent stress σ_c, as defined in 4.18.1.4, may be increased over that indicated above to a stress acceptable to LR. Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/cargo tank interaction forces due to the deflection of the double bottom and cargo tank bottoms.

4.21.3.2 Tank boundary scantlings shall meet at least the requirements of LR for deep tanks taking into account the internal pressure as indicated in 4.13.1 and any corrosion allowance required by 4.3.5 or LR 4.3.3.

4.21.3.3 The cargo tank structure shall be reviewed against potential buckling.

LR 4.21.3 The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:

- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analyses are to be performed to show that there would be no gross failure of the cargo tanks in this event.

4.21.4 **Accident design condition**

4.21.4.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 4.3.4.3 and 4.15, as relevant.

4.21.4.2 When subjected to the accidental loads specified in 4.15, the stress shall comply with the acceptance criteria specified in 4.21.3, modified as appropriate taking into account their lower probability of occurrence.

4.21.5 **Testing**

All Type A independent tanks shall be subjected to a hydrostatic or hydro-pneumatic test.

This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydro-pneumatic test is performed, the conditions should simulate, as far as practicable, the design loading of the tank and of its support structure including dynamic components, while avoiding stress levels that could cause permanent deformation.

LR 4.21.4 The following equations calculate the head of water required to model the design pressure, P_{eq}, used in the scantling calculations of the tank structure. If a hydro-pneumatic test is utilised, the head of water h_{HP} is to be taken as:

$$h_{HP} = \frac{10{,}2\,(P_{eq} - P)}{RD} + y$$

where

h_{HP} = test head of water, in metres, measured from bottom of cargo tank
P_{eq} = design pressure, in bar, at location under consideration as derived from 4.13.1
P = air test pressure, in bar
RD = $\rho/\rho_{freshwater}$
ρ = density of test fluid
$\rho_{freshwater}$ = 1000 kg/m^3 at 4°C
y = the vertical distance, in metres, from bottom of tank to the location under consideration, *see* Fig. LR 4.2

For a given head of water, h_{HP}, the load, in bar, at the location under consideration would be:

$$P_{HP,LOAD} = P + \frac{RD\,(h_{HP} - y)}{10{,}2}$$

Care is to be given that the ratio $\dfrac{P_{HP,LOAD}}{10{,}2P_{eq}} \leq 1{,}0$ at any point around the tank.

If a hydrostatic test is utilised, the head of water, h_{HS}, is to be taken as:

$$h_{HS} = \frac{10{,}2P_{eq}}{RD} - (h - y)$$

where

h_{HS} = test head of water, in metres, measured above top of cargo tank of depth h
h = height of tank as defined in 4.23.1.2 (*see also* Fig. LR 4.2)

For a given head of water, h_{HS}, the load, in bar, at the location under consideration would be:

$$P_{HS,LOAD} = \frac{RD\,[h_{HS} + (h - y)]}{10{,}2}$$

Care is to be given that the ratio $\dfrac{P_{HP,LOAD}}{10{,}2P_{eq} \leq 1{,}0}$ at any point around the tank.

The test pressure is to be not less than the MARVS.

The design pressure is not to be exceeded at any point, and the test should adequately load all areas of the tank. *See also* Pt 3, Ch 1,8.3.6 in the Rules for Ships. When testing takes place after installation of the tanks on board the ship unit, care is to be taken that the test head does not result in excessive local loading on the hull structure. For this purpose, when the cargo tanks are centrally divided with a non-perforated bulkhead, consideration will be given to testing the port and starboard sides of the tank independently.

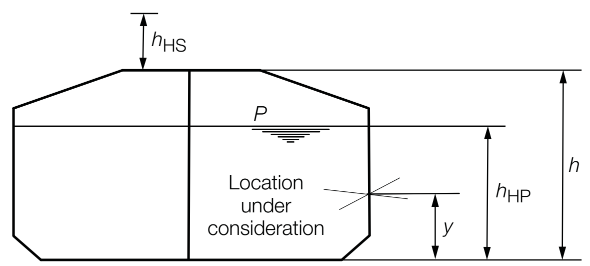


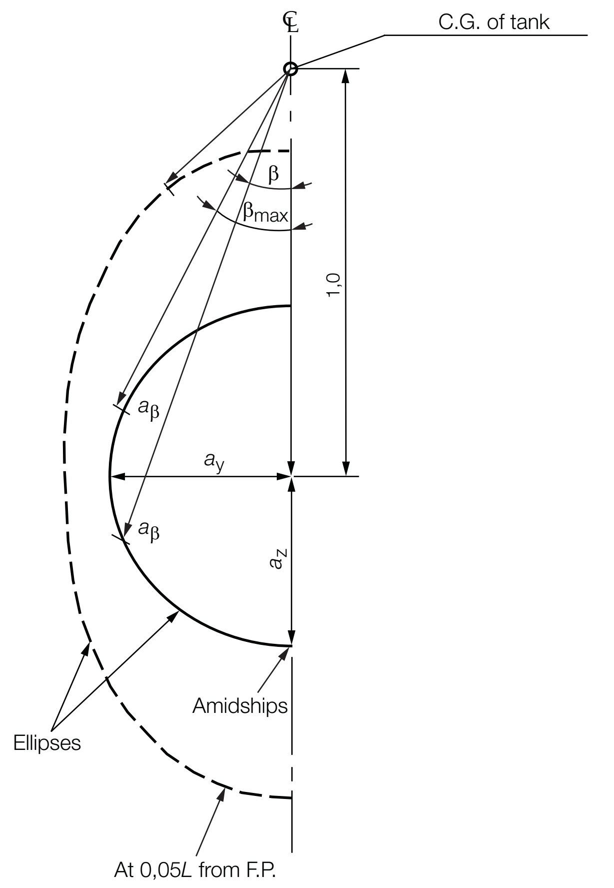
Fig. LR 4.2 Hydro-pneumatic tank testing

4.22 Type B independent tanks

4.22.1 **Design basis**

4.22.1.1 Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks) the design vapour pressure P_o shall be less than 0,07 MPa.

4.22.1.2 If the cargo temperature at atmospheric pressure is below –10°C, a partial secondary barrier with a small leak protection system is required as defined in 4.4. The small leak protection system shall be designed according to 4.7.



a_β = resulting acceleration (static and dynamic) in arbitrary direction β
a_y = transverse component of acceleration
a_z = vertical component of acceleration

Fig. 4.2 Acceleration ellipse

4.22.2 Structural analysis

4.22.2.1 The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:

- plastic deformation;
- buckling;
- fatigue failure;
- crack propagation.

Finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, shall be carried out.

4.22.2.2 A three-dimensional analysis shall be carried out to evaluate the stress levels, including interaction with the hull of the ship unit. The model for this analysis shall include the cargo tank with its supporting and keying system, as well as a reasonable part of the hull.

4.22.2.3 A complete analysis of the particular accelerations and motions of the ship unit in irregular waves, and of the response of the ship unit and its cargo tanks to these forces and motions shall be performed unless the data is available from similar ship units.

LR 4.22.1

(a) Type B independent tanks are to be subjected to a structural analysis by direct calculation procedures at a high confidence level. It is recommended that the assumptions made and the proposed calculation procedures be agreed with LR at an early stage. Where necessary, model or other tests may be required.

(b) Generally, the scantlings of cargo tanks primarily constructed of plane surfaces are not to be less than required by LR 4.21.2 for Type A independent tanks. In assessing the cumulative effect of the fatigue load, account is to be taken of the quality control aspects such as misalignment, distortion, fit-up and weld shape. A 97,7 per cent survival probability S–N curve is to be adopted in association with a cumulative damage factor C_w value of 0,1 for primary members and 0,5 for secondary members. Alternative proposals will be specially considered.

4.22.3 Ultimate design condition

4.22.3.1 **Plastic deformation**

For Type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1{,}5f$
$\sigma_b \leq 1{,}5F$
$\sigma_L + \sigma_b \leq 1{,}5F$
$\sigma_m + \sigma_b \leq 1{,}5F$
$\sigma_m + \sigma_b + \sigma_g \leq 3{,}0F$
$\sigma_L + \sigma_b + \sigma_g \leq 3{,}0F$

where:

σ_m = equivalent primary general membrane stress
σ_L = equivalent primary local membrane stress
σ_b = equivalent primary bending stress
σ_g = equivalent secondary stress
f = the lesser of (R_m/A) or (R_e/B)
F = the lesser of (R_m/C) or (R_e/D)

with R_m and R_e as defined in 4.18.1.3. With regard to the stresses σ_m, σ_L and σ_b *see also* the definition of stress categories in 4.27.3. The values *A*, *B*, *C* and *D* shall have at least the minimum values shown in Table 4.22.1.

For Type B independent tanks, primarily constructed of plane surfaces, the allowable stress levels will be specially considered: The thickness of the skin plate and the size of the stiffener shall not be less than those required for Type A independent tanks.

Table 4.22.1 Factors for determining allowable stress for Type B independent tanks

	Nickel steel and carbon manganese steels	Austenitic steels	Aluminium alloys
A	3	3,5	4
B	2	1,6	1,5
C	3	3	3
D	1,5	1,5	1,5

LR 4.22.2 The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:
- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analysis are to be performed to show that there would be no gross failure of the cargo tanks in this event.

4.22.3.2 **Buckling**
Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognised standards. The method should adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable.

4.22.4 **Fatigue design condition**

4.22.4.1 Fatigue and crack propagation assessment shall be performed in accordance with the provisions of 4.18.2. The acceptance criteria shall comply with 4.18.2.7, 4.18.2.8 or 4.18.2.9, depending on the detectability of the defect.

4.22.4.2 Fatigue analysis shall consider construction tolerances.

4.22.4.3 Where deemed necessary by the Administration, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

4.22.5 **Accident design condition**

4.22.5.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 4.3.4.3 and 4.15, as relevant.

4.22.5.2 When subjected to the accidental loads specified in 4.15, the stress shall comply with the acceptance criteria specified in 4.22.3, modified as appropriate, taking into account their lower probability of occurrence.

4.22.6 **Testing**
Type B independent tanks shall be subjected to a hydrostatic or hydro-pneumatic test as follows:
- The test shall be performed as required in 4.21.5 for Type A independent tanks
- In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90 per cent of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75 per cent of the yield strength the prototype test shall be monitored by the use of strain gauges or other suitable equipment.

4.22.7 **Marking**
Any marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

4.23 Type C independent tanks

4.23.1 Design basis

4.23.1.1 The design basis for Type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria. The minimum design pressure defined in 4.23.1.2 is intended to ensure that the dynamic stress is sufficiently low so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank.

4.23.1.2 The design vapour pressure shall not be less than:

$$P_o = 0,2 + AC(\rho_r)^{1,5} \text{ (MPa)}$$

where:

$$A = 0,00185 \left(\frac{\sigma_m}{\Delta\sigma_A}\right)^2$$

with

σ_m = design primary membrane stress

$\Delta\sigma_A$ = allowable dynamic membrane stress (double amplitude at probability level $Q = 10^{-8}$)
= 55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steel
= 25 N/mm^2 for aluminium alloy (5083-O)

C = a characteristic tank dimension to be taken as the greatest of the following:
h, 0,75b or 0,45l

with

h = height of tank (dimension in ship unit's vertical direction) (m)

b = width of tank (dimension in ship unit's transverse direction) (m)

l = length of tank (dimension in ship unit's longitudinal direction) (m)

ρ_r = the relative density of the cargo (ρ_r = 1 for fresh water) at the design temperature

When a specified design life of the tank is longer than 10^8 wave encounters $\Delta\sigma_A$ shall be modified to give equivalent crack propagation corresponding to the design life.

LR 4.23.1 Alternative means of calculating the design vapour pressure referred to in 4.23.1.2 will be accepted.

4.23.1.3 The Administration may allocate a tank complying with the criteria of Type C, minimum design pressure as in 4.23.1.2, to a Type A or Type B, dependent on the configuration of the tank and the arrangement of its supports and attachments.

LR 4.23.2 Before construction of the pressure vessels is commenced, the following particulars, where applicable, and plans are to be submitted for approval:

- Nature of cargoes, together with maximum vapour pressures and minimum liquid temperature for which the pressure vessels are to be approved, and proposed hydraulic test pressure.
- Particulars of materials proposed for the construction of the vessels.
- Particulars of refrigeration equipment.
- General arrangement plan showing location of pressure vessels in the ship unit.
- Plans of pressure vessels showing attachments, openings, dimensions, details of welded joints and particulars of proposed stress relief heat treatment.
- Plans of seatings, securing arrangements and deck sealing arrangements.
- Plans showing arrangement of mountings, level gauges and number, type and size of safety valves.

4.23.2 Shell thickness

4.23.2.1 The shell thickness shall be as follows:

.1 For pressure vessels, the thickness calculated according to 4.23.2.4 shall be considered as a minimum thickness after forming, without any negative tolerance.

.2 For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, shall not be less than 5 mm for carbon-manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys.

.3 The welded joint efficiency factor to be used in the calculation according to 4.23.2.4 shall be 0,95 when the inspection and the non-destructive testing referred to in Chapter 6 are carried out. This value may be increased up to 1,0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels LR may accept partial non-destructive examinations, but not less than those of Chapter 6, depending on such factors as the material used, the design temperature, the nil-ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0,85 should be adopted. For special materials the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.

4.23.2.2 The design liquid pressure defined in 4.13.1 shall be taken into account in the internal pressure calculations.

LR 4.23.3 The thickness of pressure parts subject to internal pressure is to be in accordance with Pt 5, Ch 11 of the Rules for Ships except that:

(a) the welded joint efficiency factor, *J*, is to be as defined in 4.23.2.1.3;

(b) the allowable stress is to be in accordance with 4.23.3.1;

(c) the constant thickness increment (0,75 mm) included in the formulae in Pt 5, Ch 11,2 of the Rules for Ships may require to be increased in accordance with 4.3.5 or LR 4.3.3.

4.23.2.3 The design external pressure P_e, used for verifying the buckling of the pressure vessels, shall not be less than that given by:

$$P_e = P_1 + P_2 + P_3 + P_4 \text{ (MPa)}$$

where

P_1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves P_1 shall be specially considered, but shall not in general be taken as less than 0,025 MPa

P_2 = the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere $P_2 = 0$

P_3 = compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both shall be taken into account

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere $P_4 = 0$.

4.23.2.4 Scantlings based on internal pressure shall be calculated as follows:
The thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 4.13.1, including flanges, should be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced in accordance with recognised Standards.

4.23.2.5 Stress analysis in respect of static and dynamic loads shall be performed as follows:

.1 Pressure vessel scantlings shall be determined in accordance with 4.23.2.4.

.2 Calculations of the loads and stresses in way of the supports and the shell attachment of the support shall be made. Loads referred to in 4.12 to 4.15 shall be used, as applicable. Stresses in way of the supporting structures shall be to a recognised standard acceptable to LR. In special cases a fatigue analysis may be required by LR.

.3 If required by LR, secondary stresses and thermal stresses shall be specially considered.

4.23.3 **Ultimate design condition**

4.23.3.1 **Plastic deformation**
For Type C independent tanks, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1{,}5f$
$\sigma_b \leq 1{,}5f$
$\sigma_L + \sigma_b \leq 1{,}5f$
$\sigma_m + \sigma_b \leq 1{,}5f$
$\sigma_m + \sigma_b + \sigma_g \leq 3{,}0f$
$\sigma_L + \sigma_b + \sigma_g \leq 3{,}0f$

where

σ_m = equivalent primary general membrane stress
σ_L = equivalent primary local membrane stress
σ_b = equivalent primary bending stress
σ_g = equivalent secondary stress
f = the lesser of (R_m/A) or (R_e/B)

with R_m and R_e as defined in 4.18.1.3. With regard to the stresses σ_m, σ_L, σ_b and σ_g *see also* the definition of stress categories in 4.27.3. The values *A* and *B* shall have at least the minimum values shown in Table 4.23.1.

Table 4.23.1 Factors for determining allowable stress for Type C independent tanks

	Nickel steels and carbon-manganese steels	Austenitic steels	Aluminium alloys
A	3	3,5	4
B	1,5	1,5	1,5

LR 4.23.4 The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:

- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analysis are to be performed to show that there would be no failure of, or leakage from, the pressure vessels in this event.

4.23.3.2 Buckling criteria shall be as follows:
The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

4.23.4 **Fatigue design condition**
For large Type C independent tanks where the cargo at atmospheric pressure is below –55°C, LR may require additional verification to check their compliance with 4.23.1.1, regarding static and dynamic stress.

4.23.5 **Accident design condition**

4.23.5.1 The tanks and the tank supporting structures shall be designed for the accidental loads and design conditions specified in 4.3.4.3 and 4.15, as relevant.

4.23.5.2 When subjected to the accidental loads specified in 4.15, the stress shall comply with the acceptance criteria specified in 4.23.3.1, modified as appropriate taking into account their lower probability of occurrence.

4.23.6 **Testing**

4.23.6.1 Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1,5 P_o. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90 per cent of the yield stress of the material. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0,75 times the yield strength, the prototype test shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

4.23.6.2 The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

4.23.6.3 The pressure shall be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

4.23.6.4 Where necessary for cargo pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in 4.23.6.1 to 4.23.6.3.

LR 4.23.5 When a hydro-pneumatic test is performed, the conditions are to simulate, so far as practicable, the actual loading of the tank and its supports.

4.23.6.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, the requirements of 4.23.6.1 shall be fully complied with.

4.23.6.6 After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in 4.22.6.1.

4.23.6.7 Pneumatic testing of pressure vessels other than cargo tanks shall only be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

4.23.7 **Marking**
The required marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

4.24 Membrane tanks

4.24.1 Design basis

4.24.1.1 The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.

4.24.1.2 A systematic approach, based on analysis and testing, shall be used to demonstrate that the system will provide its intended function in consideration of the identified in service events as specified in 4.24.2.1.

4.24.1.3 If the cargo temperature at atmospheric pressure is below –10°C a complete secondary barrier is required as defined in 4.5. The secondary barrier shall be designed according to 4.6.

4.24.1.4 The design vapour pressure P_o shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value but less than 0,07 MPa.

4.24.1.5 The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.

4.24.1.6 The thickness of the membranes is normally not to exceed 10 mm.

4.24.1.7 The circulation of inert gas throughout the primary insulation space and the secondary insulation space, in accordance with 9.2.1, shall be sufficient to allow for effective means of gas detection.

4.24.2 Design considerations

4.24.2.1 Potential incidents that could lead to loss of fluid tightness over the life of the membranes shall be evaluated. These include, but are not limited to:

.1 Ultimate design events
- Tensile failure of membranes.
- Compressive collapse of thermal insulation.
- Thermal ageing.
- Loss of attachment between thermal insulation and hull structure.
- Loss of attachment of membranes to thermal insulation system.
- Structural integrity of internal structures and their supports.
- Failure of the supporting hull structure.

.2 Fatigue design events
- Fatigue of membranes including joints and attachments to hull structure.
- Fatigue cracking of thermal insulation.
- Fatigue of internal structures and their supports.
- Fatigue cracking of inner hull leading to ballast water ingress.

.3 Accident design events
- Accidental mechanical damage (such as dropped objects inside the tank while in service).
- Accidental over-pressurisation of thermal insulation spaces.
- Accidental vacuum in the tank.
- Water ingress through the inner hull structure.

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

4.24.2.2 The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the cargo containment system shall be established during the design development in accordance with 4.24.1.2.

4.24.3 Loads, load combinations

Particular consideration shall be paid to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the cargo tank, the sloshing effects, to hull vibration effects, or any combination of these events.

4.24.4 Structural analyses

4.24.4.1 Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the cargo containment and associated structures, e.g., structures as defined in 4.9 shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the cargo containment system.

4.24.4.2 Structural analyses of the hull shall take into account the internal pressure as indicated in 4.13.1. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

4.24.4.3 The analyses referred to in 4.24.4.1 and 4.24.4.2 shall be based on the particular motions, accelerations and response of ship units and cargo containment systems.

LR 4.24.1 The hull structure supporting the membrane tank is to be incorporated into the structural finite element model of the ship unit. The scantlings of the inner hull are to be not less than required by Part 10.

LR 4.24.2 Strength analysis is also to be carried out for structures inside the tank, i.e., pump towers, and its attachments. This should take account of hydrodynamic loads due to the sloshing motion of the cargo, inertia loading due to the accelerations of the vessel, and thermal effects due to loading and unloading of the tanks in accordance with the operational philosophy. The assessment is to consider stress levels, including shear stresses in the welds, buckling, fatigue (including fatigue due to thermal effects), and vibration.

4.24.5 Ultimate design condition

4.24.5.1 The structural resistance of every critical component, sub-system, or assembly, shall be established, in accordance with 4.24.1.2, for in-service conditions.

4.24.5.2 The choice of strength acceptance criteria for the failure modes of the cargo containment system, its attachments to the hull structure and internal tank structures, shall reflect the consequences associated with the considered mode of failure.

4.24.5.3 The inner hull scantlings shall meet the requirements for deep tanks, taking into account the internal pressure as indicated in 4.13.1 and the specified appropriate requirements for sloshing load as defined in 4.14.3.

LR 4.24.3 The effects on the containment system of the 10 000 year return period wave loading are to be considered, as follows:

- Hull girder interaction loading.
- Greatest sloshing pressures distribution.

Calculations and analyses are to be performed to show that either the primary barrier or the secondary barrier should be expected to remain liquid tight in this event.

4.24.6 **Fatigue design condition**

4.24.6.1 Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.

4.24.6.2 The fatigue calculations shall be carried out in accordance with 4.18.2, with relevant requirements depending on:

- The significance of the structural components with respect to structural integrity.
- Availability for inspection.

4.24.6.3 For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, C_W shall be less than or equal to 0,5.

4.24.6.4 Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 4.18.2.8.

4.24.6.5 Structural elements not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics requirements stated in 4.18.2.9.

LR 4.24.4 Selected details of the containment system are to be investigated by fatigue analysis, which should take into account interactions with the vessel-supporting structure of the ship unit, including local, transverse and longitudinal hull girder effects, also pressure loading from the cargo and from ballast acting on the supporting structure. The number of cycles of full and partial loading and unloading are to be consistent with the operational philosophy of the unit. For investigation of the fatigue damage sustained by the secondary barrier following failure of the primary barrier, a simplified load distribution over a period of 15 days may be used, unless different project-specific requirements apply, as described in 4.6.2.1. Project-specific requirements are to be submitted for consideration.

LR 4.24.5 The fatigue damage factor of both the containment system and internal structures such as pump towers is generally to be no greater than 0,5, but is to be no greater than 0,1 for any structural detail which is not accessible for survey during the service life of the vessel and whose failure would cause the simultaneous breach of both the primary and secondary barrier, such as the attachment weld of the pump tower base support.

4.24.7 **Accident design condition**

4.24.7.1 The containment system and the supporting hull structure shall be designed for the accidental loads specified in 4.15. These loads need not be combined with each other or with environmental loads.

4.24.7.2 Additional relevant accident scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside of tanks.

4.24.8 **Design development testing**

4.24.8.1 The design development testing required in 4.24.1.2 should include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads. This will culminate in the construction of a prototype scaled model of the complete cargo containment system.

Testing conditions considered in the analytical and physical model shall represent the most extreme service conditions the cargo containment system will be likely to encounter over its life.

Proposed acceptance criteria for periodic testing of secondary barriers required in 4.6.2 is to be based on the results of testing carried out on the prototype scaled model.

4.24.8.2 The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests.

The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.

4.24.9 **Testing**
In ship units fitted with membrane cargo containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.
All hold structures supporting the membrane shall be tested for tightness before installation of the cargo containment system.
Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

4.25 Integral tanks

4.25.1 **Design basis**
Integral tanks that form a structural part of the hull and are affected by the loads that stress the adjacent hull structure shall comply with the following:

.1 The design vapour pressure P_o as defined in 4.1.2 shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly, P_o may be increased to a higher value, but less than 0,07 MPa.

.2 Integral tanks may be used for products provided the boiling point of the cargo is not below –10°C. A lower temperature may be accepted by LR subject to special consideration, but in such cases a complete secondary barrier shall be provided.

4.25.2 **Structural analysis**

LR 4.25.1 Integral tanks are to be designed and sconstructed in accordance with the requirements for cargo tanks in Part 10, using the actual cargo density and additional vapour pressure.

4.25.3 **Ultimate design condition**

LR 4.25.2 The effects of 10 000 year return period wave loading on the containment system are to be considered. This is to include:

- Hull girder loading.
- Dynamic cargo pressure loading.
- Greatest sloshing pressures distribution.

Calculations and analyses are to be performed to show that there would be no gross failure of the cargo tanks in this event.

4.25.4 **Accident design condition**

4.25.4.1 The tanks and the tank supports shall be designed for the accidental loads specified in 4.15, as relevant.

4.25.5 **Testing**
All integral tanks shall be hydrostatically or hydro-pneumatically tested. The test shall be performed so that the stresses approximate, as far as practicable, to the design stresses and that the pressure at the top of the tank corresponds at least to the MARVS.

4.26 Semi-membrane tanks

4.26.1 **Design basis**

4.26.1.1 Semi-membrane tanks are non-self-supporting tanks when in the loaded condition and consist of a layer, parts of which are supported through thermal insulation by the adjacent hull structure; the rounded parts of this layer connecting the above-mentioned supported parts are designed also to accommodate the thermal and other expansion or contraction.

4.26.1.2 The design vapour pressure P_o shall not normally exceed 0,025 MPa. If the hull scantlings are increased accordingly, and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_o may be increased to a higher value but less than 0,07 MPa.

4.26.1.3 For semi-membrane tanks the relevant requirements in this Section for independent tanks or for membrane tanks shall be applied as appropriate.

LR 4.26.1 A structural analysis and other analyses and calculations should be performed in accordance with the requirements for membrane tanks or independent tanks as appropriate, taking into account the internal pressure as indicated in 4.13.1.

4.26.1.4 In the case of semi-membrane tanks that comply in all respects with the requirements applicable to Type B independent tanks, except for the manner of support, the Administration may, after special consideration, accept a partial secondary barrier.

Part F Guidance

4.27 Guidance Notes for Chapter 4

4.27.1 **Guidance to detailed calculation of internal pressure for static design purpose**

4.27.1.1 This Section provides guidance for the calculation of the associated dynamic liquid pressure for the purpose of static design calculations. This pressure may be used for determining the internal pressure given in 4.13.1.4.
P_{gd} is the associated maximum liquid pressure determined using site-specific accelerations.
P_{eq} is to be calculated as follows:

$$P_{eq} = P_o + P_{gd} \text{ (MPa)}$$

4.27.1.2 The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the cargo due to the motions of the ship unit referred to in 4.14.1. The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations shall be calculated as follows:

$$P_{gd} = \alpha_\beta Z_\beta \left(\frac{\rho}{1{,}02 \times 10^5}\right) \text{ MPa}$$

where

α_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β, (*see* Fig. 4.2)
Note for large tanks an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations should be used

Z = largest liquid height (in metres) above the point where the pressure is to be determined measured from the tank shell in the β direction (*see* Fig. 4.3)
Tank domes considered to be part of the accepted total tank volume shall be taken into account when determining Z_β unless the total volume of tank domes V_d does not exceed the following value:

$$V_d = V_t \left(\frac{100 - FL}{FL}\right)$$

where

V_t = tank volume without any domes
FL = filling limit according to Chapter 15
ρ = maximum cargo density (kg/m^3) at the design temperature

The direction that gives the maximum value of P_{gd} shall be considered. Where acceleration components in three directions need to be considered, the ellipsoid shown in Fig. 4.4 shall be used instead of the ellipse in Fig. 4.2. The above formula applies only to full tanks.

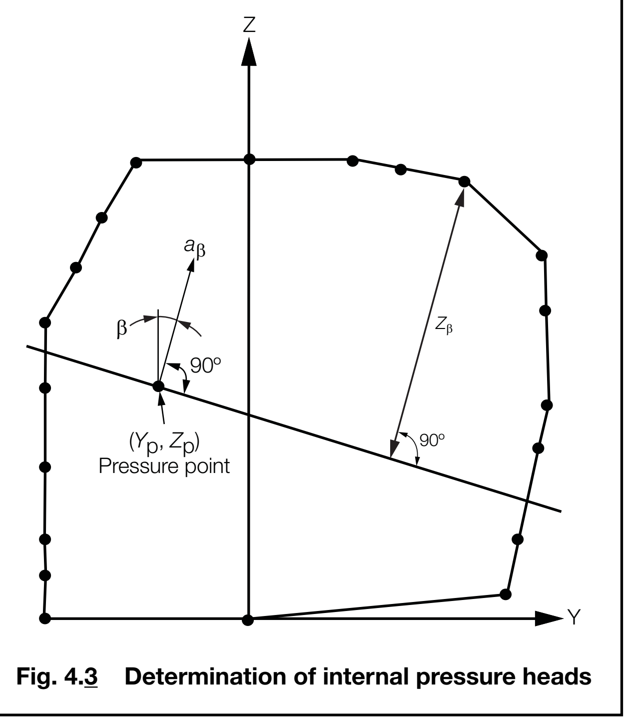
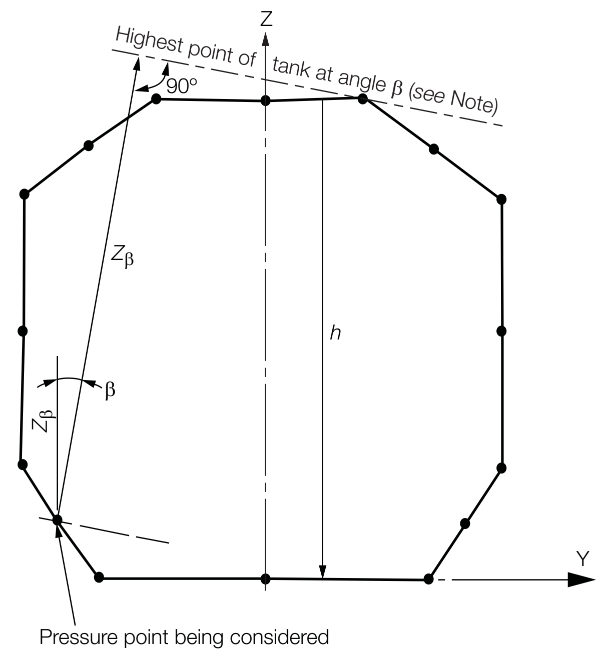


Fig. 4.3 Determination of internal pressure heads



NOTE
Small tank domes not considered to be part of the accepted total volume of the cargo tank need not be considered when determining Z_β

Fig. LR 4.3 Determination of internal pressure heads

LR 4.27.1 *See also* Fig. LR 4.3.

LR 4.27.2 Accelerations in three dimensions are to be considered for ship units with independent spherical Type B tanks for which the ellipsoid as shown in Fig. 4.4 is to be used. Where loading conditions are proposed including one or more partially filled tanks, the internal liquid pressure to be used will be specially considered. *See also* 4.14.3.

4.27.1.3 Equivalent calculation procedures may be applied.

4.27.2 Guidance formulae for acceleration components

LR 4.27.3 The following formulae are given as guidance for the determination of the maximum value of internal liquid pressure head P_{gd}, (*see* 4.27.1, internal pressure).
In the transverse direction, as shown in Fig. 4.2, the following apply:

$$a_\beta = \frac{\cos\beta . a_y^2 + a_z . a_y (\cos^2\beta . a_y^2 + \sin^2\beta . a_z^2 - \sin^2\beta)^{0,5}}{(\cos^2\beta . a_y^2 + \sin^2\beta . a_z^2)}$$

The range of angle β is:

0 to β_{max}, with $\beta_{max} = \arctan \dfrac{a_y}{(1 - a_z^2)^{0,5}}$

For the longitudinal direction, β_{max} and a_β are to be determined with a_x substituted for a_y.

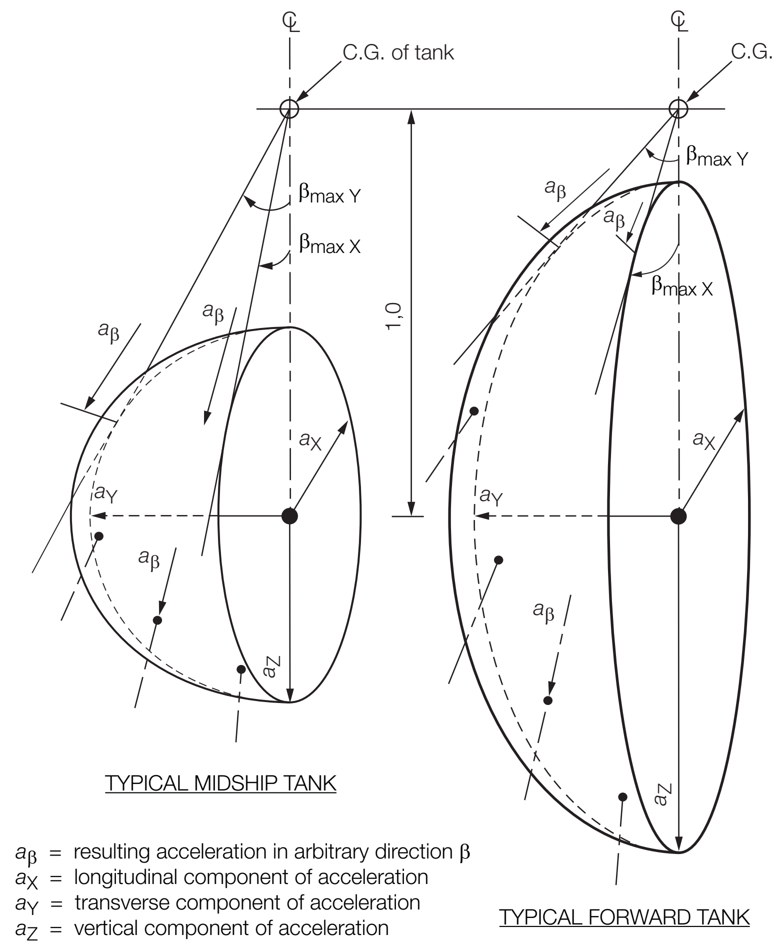


Fig. 4.4 Acceleration ellipsoids

4.27.3 **Stress categories**

4.27.3.1 For the purpose of stress evaluation, stress categories are defined in this Section.

4.27.3.2 **Normal stress** is the component of stress normal to the plane of reference.

4.27.3.3 **Membrane stress** is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

4.27.3.4 **Bending stress** is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

4.27.3.5 **Shear stress** is the component of the stress acting in the plane of reference.

4.27.3.6 **Primary stress** is a stress produced by the imposed loading, which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross deformations.

4.27.3.7 **Primary general membrane stress** is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.

4.27.3.8 **Primary local membrane stress** arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local if:

$S_1 \leq 0{,}5\sqrt{Rt}$ and

$S_2 \geq 2{,}5\sqrt{Rt}$

where:

S_1 = distance in the meridional direction over which the equivalent stress exceeds 1,1f

S_2 = distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded

R = mean radius of the vessel

t = wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded

f = allowable primary general membrane stress.

4.27.3.9 **Secondary stress** is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.

Section

5.1 General

5.1.1 The requirements of this Chapter apply to products and process piping, including vapour piping, gas fuel piping and vent lines of safety valves or similar piping. Auxiliary piping systems not containing cargo are exempt from the general requirements of this Chapter.

5.1.2 The requirements for Type C independent tanks provided in Chapter 4 may also apply to process pressure vessels. If so required, the term ‘pressure vessels’ as used in Chapter 4, covers both Type C independent tanks and process pressure vessels.

5.1.3 Process pressure vessels include surge tanks, heat exchangers and accumulators that store or treat liquid or vapour cargo.

5.2 System requirements

The cargo handling and cargo control systems shall be designed taking into account the following:

- Prevention of an abnormal condition escalating to a release of liquid or vapour cargo;
- The safe collection and disposal of cargo fluids released;
- Prevention of the formation of flammable mixtures;
- Prevention of ignition of flammable liquids or gases and vapours released;
- Limiting the exposure of personnel to fire and other hazards.

5.2.1 Arrangements – General

5.2.1.1 Any piping system that may contain cargo liquid or vapour shall:

- be segregated from other piping systems, except where interconnections are required for cargo related operations such as purging, gas freeing or inerting. The requirements of 9.4.4 shall be taken into account with regard to preventing back flow of cargo. In such cases, precautions shall be taken to ensure that cargo or cargo vapour cannot enter other piping systems through the interconnections;
- except as provided in Chapter 16, not pass through any accommodation space, service space or control station or through a machinery space other than a cargo machinery space;
- be connected to the cargo containment system directly from the weather decks except where pipes installed in a vertical trunkway or equivalent are used to traverse void spaces above a cargo containment system and except where pipes for drainage, venting or purging traverse cofferdams;
- be located in the cargo area above the weather deck except for bow or stern loading and unloading arrangements in accordance with 3.8, emergency cargo jettisoning piping systems in accordance with 5.3.1, turret compartment systems in accordance with 5.3.3 and except in accordance with Chapter 16; and
- be located inboard of the transverse tank location requirements of 2.4.1 except for emergency cargo jettisoning piping systems.

5.2.1.2 Suitable means shall be provided to relieve the pressure and remove liquid cargo from discharging headers; likewise, any piping between the outermost discharge valves and loading arms or cargo hoses or any other location prior to the outermost valve that may be subject to pressurisation during discharging operations.

5.2.1.3 Piping systems carrying fluids for direct heating or cooling of cargo shall not be led outside the cargo area unless a suitable means is provided to prevent or detect the migration of cargo vapour outside the cargo area. *(See also* 13.6.2.6).

5.2.1.4 Relief valves discharging liquid cargo from the piping system shall discharge into the cargo tanks. Alternatively, they may discharge to the flare system which is to be designed in accordance with API 521 *Guide for Pressure-relieving and Depressuring Systems: Petroleum petrochemical and natural gas industries-Pressure relieving and depressuring systems*. Where required to prevent overpressure in downstream piping, relief valves on cargo pumps shall discharge to the pump suction.

5.3 Arrangements for cargo piping outside the cargo area

5.3.1 **Emergency cargo jettisoning**
If fitted, an emergency cargo jettisoning piping system shall comply with 5.2.1 as appropriate and may be led aft, external to accommodation spaces, service spaces or control stations or machinery spaces, but shall not pass through them. If an emergency cargo jettisoning piping system is permanently installed, a suitable means of isolating the piping system from the cargo piping shall be provided within the cargo area.

5.3.2 **Bow and stern loading arrangements**
Subject to the requirements of 3.8, this Section and 5.10.1, cargo piping may be arranged to permit bow or stern loading and unloading.

1. Arrangements shall be made to allow such piping to be purged and gas freed after use. When not in use the spool pieces shall be removed and the pipe ends blank flanged. The vent pipes connected with the purge shall be located in the cargo area.

5.3.3 **Turret compartment transfer systems**
For the transfer of liquid or vapour cargo through an internal turret arrangement located, outside the cargo area, the piping serving this purpose shall comply with 5.2.1 as applicable, 5.10.2 and the following;

.1 Piping shall be located above the weather deck except for the connection to the turret.
.2 Portable arrangements shall not be permitted.
.3 Arrangements shall be made to allow such piping to be purged and gas freed after use. When not in use the spool pieces for isolation from the cargo piping shall be removed and the pipe ends blank flanged. The vent pipes connected with the purge shall be located in the cargo area.

5.3.4 **Gas fuel piping systems**
Gas fuel piping in machinery spaces shall comply with all applicable Sections of this Chapter in addition to the requirements of Chapter 16.

5.4 Design pressure

5.4.1 The design pressure P_o, used to determine minimum scantlings of piping and piping system components, shall be not less than the maximum gauge pressure to which the system may be subjected in service. The minimum design pressure used shall not be less than 1 MPa except for; open ended lines or pressure relief valve discharge lines where it shall be not less than the lower of 0,5 MPa, or 10 times the relief valve set pressure.

5.4.2 The greater of the following design conditions shall be used for piping, piping systems and components, based on the cargoes being carried:

.1 for vapour piping systems or components that may be separated from their relief valves and which may contain some liquid: the saturated vapour pressure at a design temperature of 45°C. Higher or lower values may be used (*see* 4.13.1.2); or
.2 for systems or components that may be separated from their relief valves and which contain only vapour at all times: the superheated vapour pressure at 45°C. Higher or lower values may be used, *see* 4.13.1.2, assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or
.3 the MARVS of the cargo tanks and cargo processing systems; or
.4 the pressure setting of the associated pump or compressor discharge relief valve; or
.5 the maximum total discharge or loading head of the cargo piping system considering all possible pumping arrangements or the relief valve setting on a pipeline system.

5.4.3 Those parts of the liquid piping systems that may be subjected to surge pressures shall be designed to withstand this pressure.

5.4.4 The design pressure of the outer pipe or duct of gas fuel systems shall not be less than the maximum working pressure of the inner gas pipe. Alternatively for gas fuel piping systems with a working pressure greater than 1 MPa, the design pressure of the outer duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

5.5 Cargo system valve requirements

Every cargo tank and piping system shall be fitted with manually-operated valves for isolation purposes as specified in this Section.
In addition, remotely operated valves shall also be fitted, as appropriate, as part of the emergency shut-down (ESD) system. The purpose of this ESD system is to stop cargo flow or leakage in the event of an emergency when cargo liquid or vapour transfer is in progress.
The ESD system is intended to return the cargo system to a safe static condition so that any remedial action can be taken. Due regard shall be given in the design of the ESD system to avoid the generation of surge pressures within the cargo transfer pipework.
The equipment to be shut down on ESD activation includes; manifold valves during loading or discharge, any pump or compressor etc transferring cargo internally or externally (e.g. to a shuttle tanker) plus cargo tank valves if the MARVS exceeds 0,07 MPa.

5.5.1 **Cargo tank connections**
All liquid and vapour connections, except for safety relief valves and liquid level gauging devices, shall have shut-off valves located as close to the tank as practicable. These valves shall provide full closure and shall be capable of local manual operation; they may also be capable of remote operation.
For cargo tanks with a MARVS exceeding 0,07 MPa, the above connections shall also be equipped with remotely controlled ESD valves. These valves shall be located as close to the tank as practicable. A single valve may be substituted for the two separate valves provided the valve complies with the requirements of 18.10.2 and provides full closure of the line.

5.5.2 **Cargo offloading connections**
The offloading station is to provide a remotely controlled ESD valve prior to the hose connection to prevent liquid and vapour to or from the facility in the event of an incident. In the event that one or more transfer hoses are not used a manual and controlled by permit (or similar method) stop valve is to be provided prior to the hose connection.
In the event that the vapour return line is closed the ESD system is to be designed to stop all cargo pumping.
If the cargo tank MARVS exceeds 0,07 MPa an additional manual valve shall be provided for each transfer connection in use, and may be inboard or outboard of the ESD valve to suit the design of the ship unit.

5.5.3 Cargo tank connections for gauging or measuring devices need not be equipped with excess flow valves or ESD valves provided that the devices are constructed so that the outward flow of tank contents cannot exceed that passed by a 1,5 mm diameter circular hole.

5.5.4 All pipelines or components which may be isolated in a liquid full condition shall be protected with relief valves for thermal expansion and evaporation.

5.5.5 All pipelines or components which may be isolated automatically due to a fire with a liquid volume of more than 0,05 m^3 entrapped shall be provided with PRVs sized for a fire condition.

5.6 Cargo transfer arrangements

5.6.1 Where cargo transfer is by means of cargo pumps that are not accessible for repair with the tanks in service, at least two separate means shall be provided to transfer cargo from each cargo tank and the design shall be such that failure of one cargo pump or means of transfer will not prevent the cargo transfer by another pump or pumps, or other cargo transfer means.

5.6.2 The procedure for transfer of cargo by gas pressurisation shall preclude lifting of the relief valves during such transfer. Gas pressurisation may be accepted as a means of transfer of cargo for those tanks where the design factor of safety is not reduced under the conditions prevailing during the cargo transfer operation. If the cargo tank relief valves or set pressure are changed for this purpose, as is permitted in accordance with 8.2.7 and 8.2.8 the new set pressure is not to exceed P_h as is defined in 4.13.1.

5.6.3 **Vapour return connections**
Connections for vapour return from the shuttle tanker to the ship unit shall be provided.

5.6.4 **Cargo tank vent piping systems**
The pressure relief system shall be connected to a vent piping system designed to minimise the possibility of cargo vapour accumulating on the decks, or entering accommodation spaces, service spaces, control stations and machinery spaces, or other spaces where it may create a dangerous condition.

5.6.5 **Cargo sampling connections**

5.6.5.1 Connections to cargo piping systems for taking cargo liquid samples shall be clearly marked and shall be designed to minimise the release of cargo vapours.

5.6.5.2 Liquid sampling systems shall be provided with two valves on the sample inlet. One of these valves shall be of the multi-turn type to avoid accidental opening, and shall be spaced far enough apart to ensure that they can isolate the line if there is blockage, by ice or hydrates for example.

5.6.5.3 On closed loop systems, the valves on the return pipe shall also comply with 5.6.5.2.

5.6.5.4 The connection to the sample container shall comply with a recognised Standard and be supported so as to be able to support the weight of a sample container. Threaded connections shall be tack-welded, or otherwise locked, to prevent them being unscrewed during the normal connection and disconnection of sample containers. The sample connection shall be fitted with a closure plug or flange to prevent any leakage when the connection is not in use.

5.6.5.5 Sample connections used only for vapour samples may be fitted with a single valve in accordance with 5.5, 5.8 and 5.13, and shall also be fitted with a closure plug or flange.

5.6.5.6 Sampling operations shall be undertaken as in 18.9.

5.6.6 **Cargo filters**
It is anticipated that liquefied gas facilities will remove contaminants before liquefaction. In the event that further filtration is anticipated, e.g., cool down during commissioning, the following shall be applied.
The cargo liquid and vapour systems shall be capable of being fitted with filters to protect against damage by foreign objects. Such filters may be permanent or temporary, and the standards of filtration shall be appropriate to the risk of debris, etc., entering the cargo system. Means shall be provided to indicate that filters are becoming blocked. Means shall be provided to isolate, depressurise and clean the filters safely.

5.7 Installation requirements

5.7.1 **Design for expansion and contraction**

Provision shall be made to protect the piping, piping system and components and cargo tanks from excessive stresses due to thermal movement and from movements of the tank and hull structure. The preferred method outside the cargo tanks is by means of offsets, bends or loops, but multi-layer bellows may be used if offsets, bends or loops are not practicable.

5.7.2 **Precautions against low temperature**

Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material. Where liquid piping is dismantled regularly, or where liquid leakage may be anticipated, such as at cargo transfer connections and at pump seals, protection for the hull beneath shall be provided.

5.7.3 **Cryogenic protection**

Cryogenic protection against spills is to be provided for temperatures below –110°C, such systems are to provide adequate coverage of hull, main decks, process decks, process support structures and other vulnerable equipment within the process area. These systems are to consider spillage, cryogenic jets and cryogenic pooling, and their size and scope are to be based on the process area inventories of the cryogenic material. The design of such systems is to ensure that they are constantly available and not reactive to an event.

Areas of the facility used for the discharge of cryogenic material may employ a water curtain for protection during such operations and is additional to the requirements of 11.3.1.4.

5.7.4 **Bonding**

Where tanks or cargo piping and piping equipment are separated from the structure of the ship unit by thermal isolation, provision shall be made for electrically bonding both the piping and the tanks. All gasketed pipe joints and hose connections shall be electrically bonded. Except where bonding straps are used, it shall be demonstrated that the electrical resistance of each joint or connection is less than 1 MΩ.

5.8 Piping fabrication and joining details

5.8.1 **General**

The requirements of this Section apply to piping inside and outside the cargo tanks. Relaxation from these requirements may be accepted, in accordance with recognised Standards for piping inside cargo tanks and open-ended piping.

5.8.2 **Direct connections**

The following direct connection of pipe lengths, without flanges, may be considered:

.1 Butt welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than –10°C, butt welds shall be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back up on the first pass. For design pressures in excess of 1 MPa and design temperatures of –10°C or colder, backing rings shall be removed.

.2 Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognised Standards, shall only be used for instrument lines and open ended lines with an external diameter of 50 mm or less and design temperatures not colder than –55°C.

.3 Screwed couplings complying with recognised Standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

5.8.3 **Flanged connections**

5.8.3.1 Flanges in flange connections shall be of the welded neck, slip-on or socket welded type.

5.8.3.2 Flanges shall comply with recognised Standards for their type, manufacture and test. For all piping except open ended, the following restrictions apply:

.1 For design temperatures colder than –55°C, only welded neck flanges shall be used.

.2 For design temperatures colder than –10°C, slip-on flanges shall not be used in nominal sizes above 100 mm and socket welded flanges shall not be used in nominal sizes above 50 mm.

5.8.4 **Expansion joints**

Where bellows and expansion joints are provided in accordance with 5.7.1, the following requirements apply:

.1 If necessary, bellows should be protected against icing.

.2 Slip joints shall not be used except within the cargo tanks.

5.8.5 **Other connections**

Piping connections shall be joined in accordance with 5.8.2 to 5.8.4, but for other exceptional cases the Administration may consider alternative arrangements.

5.9 Welding, post-weld heat treatment and non-destructive testing

5.9.1 **General**

Welding shall be carried out in accordance with Chapter 6.

5.9.2 **Post-weld heat treatment**
Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon manganese and low alloy steels. LR may waive the requirements for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

5.9.3 **Non-destructive testing**
In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the requirements of this paragraph, the following tests shall be required:

.1 100 per cent radiographic or ultrasonic inspection of butt-welded joints for piping systems with design temperatures colder than –10°C, or with inside diameters of more than 75 mm, or wall thicknesses greater than 10 mm;

.2 When such butt-welded joints of piping sections are made by automatic welding procedures approved by LR, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10 per cent of each joint. If defects are revealed the extent of examination shall be increased to 100 per cent and shall include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently; and

.3 For other butt-welded joints of pipes not covered by 5.9.3.1 and 5.9.3.2, spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10 per cent of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection.

5.10 Installation requirements for cargo piping outside the cargo area

5.10.1 **Bow and stern loading arrangements**
The following provisions apply to cargo piping and related piping equipment located outside the cargo area:

.1 Cargo piping and related piping equipment outside the cargo area shall have only welded connections. The piping outside the cargo area shall run on the weather decks and shall be at least 0,8 m inboard, except for cargo transfer connection piping. Such piping shall be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location it shall also be capable of being separated, by means of a removable spool piece and blank flanges, when not in use.

.2 The piping is to be full penetration butt-welded and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at the cargo transfer connections.

5.10.2 **Turret compartment transfer systems**
The following provisions apply to liquid and vapour cargo piping where it is run outside the cargo area:

.1 Cargo piping and related piping equipment outside the cargo area shall have only welded connections.

.2 The piping shall be full penetration butt-welded, and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping shall only be permitted within the cargo area and at connections to cargo hoses and the turret connection.

5.10.3 **Gas fuel piping**
Gas fuel piping, as far as practicable, shall have welded joints. Those parts of the gas fuel piping that are not enclosed in a ventilated pipe or duct according to 16.4.3, and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be subjected to full radiographic or ultrasonic inspection.

5.11 Piping system component requirements

5.11.1 **Piping scantlings**
Piping systems shall be designed in accordance with recognised Standards.

5.11.2 The following criteria shall be used for determining pipe wall thickness.
The wall thickness of pipes shall not be less than:

$$T = \frac{t_o + b + c}{1 - \frac{a}{100}} \text{ (mm)}$$

where

t_o = theoretical thickness

$$t_o = \frac{P\,D}{2K\,e + P} \text{ (mm)}$$

with

P = design pressure (MPa) referred to in 5.4
D = outside diameter (mm)
K = allowable stress (N/mm^2) referred to in 5.11.3
e = efficiency factor equal to 1,0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non destructive testing on welds is carried out in accordance with Recognised Standards. In other cases an efficiency factor of less than 1,0, in accordance with recognised Standards, may be required depending on the manufacturing process

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b should be:

$$b = \frac{D\,t_0}{2,5r} \text{ (mm)}$$

with

r = mean radius of the bend (mm)

c = corrosion allowance (mm). If corrosion or erosion is expected the wall thickness of the piping shall be increased over that required by other design requirements. This allowance shall be consistent with the expected life of the piping

a = negative manufacturing tolerance for thickness (per cent).

5.11.3 Allowable stress

5.11.3.1 For pipes, the allowable stress to be considered in the formula for t in 5.11.2 is the lower of the following values:

R_m/A or R_e/B

where

R_m = specified minimum tensile strength at room temperature (N/mm^2)

R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress strain curve does not show a defined yield stress, the 0,2 per cent proof stress applies.

The values of A and B shall have values of at least A = 2,7 and B = 1,8.

5.11.3.2 The minimum wall thickness shall be in accordance with recognised Standards.

5.11.3.3 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by 5.11.2 or, if this is impracticable or would cause excessive local stresses, these loads shall be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to; supporting structures, deflections of the ship unit, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

5.11.4 High pressure gas fuel outer pipes or ducting scantlings

In fuel gas piping systems of design pressure greater than the critical pressure, the tangential membrane stress of a straight section of pipe or ducting shall not exceed the tensile strength divided by 1,5 (i.e., R_m/1,5) when subjected to the design pressure specified in 5.4. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

5.11.5 Stress analysis

When the design temperature is –110°C or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hogging and sagging of the ship unit for each branch of the piping system shall be submitted to LR. For temperatures above –110°C, a stress analysis may be required by LR in relation to such matters as the design or stiffness of the piping system and the choice of materials. In any case, consideration should be given to thermal stresses even though calculations are not submitted. The analysis may be carried out according to a Code of Practice acceptable to LR.

5.11.6 Flanges, valves and fittings

5.11.6.1 Flanges, valves and other fittings shall comply with recognised Standards, taking into account the material selected and the design pressure defined in 5.4. For bellows expansion joints used in vapour service, a lower minimum design pressure may be accepted.

5.11.6.2 For flanges not complying with a recognised Standard, the dimensions of flanges and related bolts shall be to the satisfaction of LR.

5.11.6.3 All emergency shutdown valves shall be of the 'fire closed' type. (*See* 5.13.1.1 and 18.10.2).

5.11.6.4 The design and installation of expansion bellows shall be in accordance with recognised Standards and be fitted with means to prevent damage due to over-extension or compression.

5.11.7 Ship unit cargo hoses

5.11.7.1 Liquid and vapour hoses used for cargo transfer shall be compatible with the cargo and suitable for the cargo temperature.

5.11.7.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose will be subjected to during cargo transfer.

5.11.7.3 Each new type of cargo hose, complete with end fittings, shall be prototype-tested at a normal ambient temperature, with 200 pressure cycles from zero to at least twice the specified maximum working pressure. After this cycle pressure test has been carried out, the prototype test shall demonstrate a bursting pressure of at least 5 times its specified maximum working pressure at the upper and lower extreme service temperature. Hoses used for prototype testing shall not be used for cargo service. Thereafter, before being placed in service, each new length of cargo hose produced shall be hydrostatically tested at ambient temperature to a pressure not less than 1,5 times its specified maximum working pressure, but not more than two fifths of its bursting pressure. The hose shall be stencilled or otherwise marked with the date of testing, its specified maximum working pressure and, if used in services other than ambient temperature services, its maximum and minimum service temperature, as applicable. The specified maximum working pressure shall not be less than 1 MPa.

5.12 Materials

5.12.1 The choice and testing of materials used in piping systems shall comply with the requirements of Chapter 6, taking into account the minimum design temperature. However, some relaxation may be permitted in the quality of material of open ended vent piping providing the temperature of the cargo at the pressure relief valve setting is not colder than –55°C and provided no liquid discharge to the vent piping can occur. Similar relaxations may be permitted under the same temperature conditions to open ended piping inside cargo tanks, excluding discharge piping and all piping inside membrane and semi membrane tanks.

5.12.2 Materials having a melting point below 925°C shall not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation shall be provided.

5.12.3 **Cargo piping insulation system**

5.12.3.1 Cargo piping systems shall be provided with a thermal insulation system as required to minimise heat leak into the cargo during transfer operations and to protect personnel from direct contact with cold surfaces.

5.12.3.2 Where applicable, due to location or environmental conditions, insulation materials should have suitable properties of resistance to fire and flame spread and should be adequately protected against penetration of water vapour and mechanical damage.

5.12.4 Where the cargo piping system is of a material susceptible to stress corrosion cracking in the presence of a salt laden atmosphere, adequate measures to avoid this occurring should be taken by considering material selection, protection of exposure to salty water and/or readiness for inspection.

5.13 Testing requirements

5.13.1 **Type testing of piping components**

5.13.1.1 **Valves**
Reference is made to the SIGTTO publication *The Selection and Testing of Valves for LNG Applications*.
Each type of piping component shall be subject to the following type tests:
Each type of piping component intended to be used at a working temperature below –55°C shall be subject to the following type tests:

.1 Each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures for bi-directional flow and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates shall be to the requirements of LR. During the testing satisfactory operation of the valve shall be verified.

.2 The flow or capacity shall be certified to a recognised Standard for each size and type of valve.

.3 Pressurised components shall be pressure tested to at least 1,5 times the rated pressure.

.4 For emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard acceptable to the Administration. Reference is made to API Std 607 *Fire Test for Soft Seated Quarter Turn Valves*.

5.13.1.2 **Expansion bellows**
The following type tests shall be performed on each type of expansion bellows intended for use on cargo piping outside the cargo tank and where required by the Recognised Organisation, on those installed within the cargo tanks:

.1 Elements of the bellows, not pre-compressed, shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes.

.2 A pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.

.3 A cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.

.4 A cyclic fatigue test (deformation of the ship unit) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2 000 000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, deformation loads from the ship unit are actually experienced.

5.13.2 **System testing requirements**

5.13.2.1 The requirements of this Section apply to piping inside and outside the cargo tanks.

5.13.2.2 After assembly, all cargo and process piping shall be subjected to a strength test with a suitable fluid. The test pressure is to at least 1,5 times the design pressure (1,25 times the design pressure where the test fluid is compressible) for liquid lines and 1,5 times the maximum system working pressure (1,25 times the maximum system working pressure where the test fluid is compressible) for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation onboard the ship unit. Joints welded onboard shall be tested to at least 1,5 times the design pressure.

5.13.2.3 After assembly onboard, each cargo and process piping system shall be subjected to a leak test using air, or other suitable medium to a pressure depending on the leak detection method applied.

5.13.2.4 In double wall gas fuel piping systems the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

5.13.2.5 All piping systems, including valves, fittings and associated equipment for handling cargo or vapours, shall be tested under normal operating conditions not later than at the first loading operation, in accordance with recognised Standards.

LR 5.14 Cryogenic liquefied gas spill control

LR 5.14.1 General

LR 5.14.1.1. Cryogenic liquefied gases are liquids that are kept in their liquid state at very low temperatures.

LR 5.14.1.2 Cryogenic liquefied gas release can cause or contribute to the failure of safety critical structures and equipment due to the embrittlement of steel or control systems in contact with the release.

LR 5.14.1.3 This Section considers the brittle fracture of critical structures and equipment as well as the failure of control systems due to cooling to a critical temperature following a leak of a cryogenic liquefied gas.

LR 5.14.2 Scope

LR 5.14.2.1 The requirements of this Section are additional to those of this Chapter and are applicable to offshore units which are intended for the processing and carriage of cryogenic liquefied gas(es) in bulk.

LR 5.14.3 Application

LR 5.14.3.1 The following Rules are applicable to the cryogenic process equipment, associated cryogenic piping systems and pipework serving essential safety systems in way of or within the vicinity of the cryogenic process area on board an offshore unit.

LR 5.14.3.2 Requirements for fire safety are not included in these Rules; instead they are subject to the satisfactory requirements of the National Administration.

LR 5.14.4 Documents and plans

LR 5.14.4.1 Plans, together with particulars as detailed in this Section, are to be submitted for approval. Any subsequent modifications are subject to approval before being put into operation.

LR 5.14.4.2 A description of the expected method of operation of the process plant and a diagram showing the process flow are to be submitted.

LR 5.14.4.3 Particulars of the proposals for isolating the offshore unit from the shore/subsea installation and/or vessels, where applicable, are to be submitted, including:

- Feedstock supply and product discharge, with details of the arrangements showing the location of shut-off valves and of the control and indicating stations.
- The process plant parameters and analysis of transient conditions under which emergency shut-down will be initiated and the time estimated to obtain a safe environment.
- The proposed emergency procedures for controlled shut-down of the process plant, i.e., depressurising, inerting, etc., and the arrangements for the continued operation of the essential services necessary to allow for such controlled shut-down under the emergency conditions.

LR 5.14.4.4 A risk assessment, or equivalent method acceptable to LR, is to be carried out for cryogenic liquefied gas spill.

LR 5.14.4.5 Risk assessment is to be carried out by representative specialists from the Owner, Builder and independent body/third party.

LR 5.14.4.6 A summary of the risk assessment is to be documented and submitted to LR for “for review only”.

LR 5.14.4.7 Depending on the likelihood and consequence of failures identified in the risk analysis, typical prevention and mitigation measures should be proposed or referred to.

LR 5.14.7.8 Each component of the cryogenic process equipment such as, and not limited to tanks, pumps, compressors, pipelines, valves and vessels must be considered as a potential source of cryogenic release. Special consideration shall be made for components which are not generally considered to be a sources of cryogen release such as all welded pipelines, pressure vessels and associated welded instrumentation

LR 5.14.5 Detection of cryogenic spill

LR 5.14.5.1 A detection system shall be provided to give warning of any cold spot due to the leakage of LNG or natural gas.

LR 5.14.5.2 Detecting of cold spots may include but are not limited to:

- Gas detection.
- Metal temperature monitoring.
- Thermal imaging.
- Visual inspection.
- Video monitoring.
- Monitoring of process parameters.

LR 5.14.5.3 The equipment installed for cold spot detection is to be approved by LR.

LR 5.14.6 Cryogenic spill containment and suppression

LR 5.14.6.1 Isolation valves, for inventory control purposes, must be located as close as practically possible to vessels or equipment.

LR 5.14.6.2 Inventory isolation valves that are located within a recognised fire zone shall be protected against fire and explosion effects.

LR 5.14.6.3 For inventory control under fire conditions consideration shall be given to automatic operation of valves where:

- Manual operation of valves may involve danger to operators;
- require a rapid response;
- need unusual strength or dexterity.

LR 5.14.6.4 Where inventory isolation valves are automatically operated, they will need to be an emergency shut-down valves which are actuated by a process trip/alarm and/or actuated by gas or fire alarm.

LR 5.14.7 Blowdown/depressurisation

LR 5.14.7.1 The design of the liquefied gas process piping system is to allow the safe depressurisation or blowing down of the unaffected and isolated sections of the process system either to safely flare or drain inventory back to cargo tanks.

LR 5.14.7.2 Where a liquid blowdown system is provided in the process plant, the design and installation are to make adequate provision for the effects of back pressure in the system and vapour flash off when the pressures of liquids in the blowdown system are reduced.

LR 5.14.7.3 Substances which will react with each other are to be provided with separate systems.

LR 5.14.8 Limiting cryogenic spills and releases

LR 5.14.8.1 Bunds, drip trays and spray guards resistant to cryogenic temperatures must be provided at manifolds and flanged connections in the liquefied gas system.

LR 5.14.8.2 Liquefied gas process equipment and associated piping system are to be located within a bunded area with provision for the drainage of rain or fire water.

LR 5.14.8.3 The liquefied gas process piping and associated equipment arrangement is to not allow the possibility for liquefied gas spills or leaks to accumulate under any storage vessels or equipment.

LR 5.14.8.4 The bunding is to consist of a raised impermeable material, able to withstand the static pressure and temperature of the cryogenic liquid spilled, around the perimeter of an impounding area.

LR 5.14.8.5 The capacity of the bunded area shall be greater than the amount of liquid which would be spilled by breakage of the pipe with the highest leakage rate for the time necessary for detection and for interruption of flow.

LR 5.15 Liquefied gas transfer systems – General requirements

LR 5.15.1 Application

LR 5.15.1.1 The Rules contained within this Chapter apply to liquefied gas transfer system(s) installed on board offshore units, for the purpose of transferring liquefied gas between an offshore unit and a commercially trading Liquefied gas tanker. The requirements are in addition to the relevant Rules contained within the *Rules and Regulations for the Classification of Offshore Units* (hereinafter referred to as the Rules for Offshore Units).

LR 5.15.1.2 The extent of liquefied gas transfer system and facilities are subject to agreement between the designer and Owner/Operator. The classification approval process will involve assessment of the safety of the proposed facilities from concept to through life operability and de-commissioning. Liquefied gas transfer operations are extremely hazardous and those involved in the development of such systems need to address safety issues to minimise the risks to the offshore unit, personnel and the environment. Operational procedures and regular crew training are essential to minimise these risks and reduce hazards to as low as reasonably practicable. Attention is drawn to the following guidance documents and standards:

- Ship to ship transfer guide (Liquefied Gases) 2nd Edition, published by OCIMF/SIGTTO.
- ICS/OCIMF 'Ship to ship Transfer Guide (petroleum) 4th edition'.
- OCIMF 'Mooring Equipment Guideline 3'.
- EN 1474 'Installation and Testing for Liquefied Natural Gas – Design and Testing of Marine Transfer Systems'.

LR 5.15.1.3 Requirements additional to these Rules may be imposed by the National Authority with whom the offshore unit is registered and/or by the Administration within whose territorial jurisdiction the offshore unit is intended to operate.

LR 5.15.1.4 Requirements for fire safety are not included in these Rules; instead they are subject to the satisfactory requirements of the National Administration.

LR 5.15.2 Surveys

LR 5.15.2.1 The survey of these items is to be arranged to coincide with hull and machinery surveys. *See* Periodical Survey Chapter and Section.

LR 5.15.3 Design and operating principles

LR 5.15.3.1 Liquefied gas transfer systems are to be designed in accordance with user defined operating and performance criteria taking account of the offshore unit type and service operating envelope.

LR 5.15.3.2 Liquefied gas transfer systems are to be capable of operation within specified operating conditions that include maximum sea states, wind conditions and those identified in the Rules for Offshore Units.

LR 5.15.3.3 Liquefied gas transfer systems are to be designed and installed such that degradation or failure of any liquefied gas transfer systems will not render another essential system inoperable.

LR 5.15.3.4 Release of liquefied gas due to the failure, leak or rupture of the system must not lead to catastrophic failure of the hull structure.

LR 5.15.3.5 Liquefied gas transfer systems are to be capable of operating within the normal vibration modes and cyclic loads of the vessel.

LR 5.15.3.6 Liquefied gas transfer systems are to be designed to minimise the risks to the hull structure, personnel and the environment. The risks involved in carrying out identified hazardous activities are to be as low as reasonably practicable.

LR 5.15.4 Acceptance criteria

LR 5.15.4.1 **General.** The acceptance process will validate conformity of liquefied gas transfer system to the provisions of classification for systems within the vessel type by assessing such systems for compliance with Lloyd's Register's (hereinafter referred to as 'LR') Rules for Offshore Units, and specified standards and codes.

LR 5.15.4.2 A safety and reliability analysis is to be carried out to demonstrate that the liquefied gas transfer system includes risk mitigation so that the level of safety and reliability is equivalent to that associated with the current transfer of liquefied gas fluid from shore to ship (i.e., SIGTTO OCIMF). The analysis is to be carried out in accordance with acceptable National or International Standards.

LR 5.15.4.3 The analysis is to include identification of the hazards associated with the operation and maintenance of the liquefied gas transfer system under all normal and reasonably foreseeable abnormal conditions, and, in the event of a single failure, the potential effects on the safety of the offshore unit and its occupants, its machinery and equipment, and the environment.

LR 5.15.4.4 The analysis is to be carried out in accordance with an acceptable industry or International Standard, using techniques appropriate for the analysis, and is to include arrangements to mitigate the potential effects of the hazards identified.

LR 5.15.4.5 The analysis is to consider at least and not limited to the following hazards:

- low rate gas leakage, e.g., from joints, seals, etc.;
- high rate gas leakage, e.g., from pipe rupture;
- corrosion/erosion in gas piping, components and tanks;
- mechanical failure of liquefied gas transfer system, equipment or components;
- control/electrical failure of ESD system, ERS and electrical isolation in liquefied gas transfer system, equipment or components;
- manufacturing defects in equipment and machinery;
- human error in operation, maintenance, inspection and testing liquefied gas transfer, equipment and components;
- location of gas-containing tanks, piping, machinery, equipment and components;
- fire in areas or spaces containing tanks, piping, machinery, equipment and components;
- fire adjacent to areas or spaces containing liquefied gas transfer system, cargo tanks, piping, machinery, equipment and components;
- failure of lifting devices due to heavy loads, maximum sea states, wind conditions; and
- failure of quick coupling system.

LR 5.15.4.6 In order to facilitate the proper selection and installation of equipment to be used safely in areas where explosive gas atmospheres may occur, an area classification study, in accordance with an alternative relevant International or National Standard such as IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres* is to be carried out.

LR 5.15.4.7 To ensure that mechanical equipment located in hazardous areas does not represent a source of ignition, an ignition hazard assessment, in accordance with an acceptable National or International Standard such as EN 13463-1, is to be carried out.

LR 5.15.4.8 The assessment process for liquefied gas transfer systems will consider all aspects of the system including offshore unit to ship dynamic interaction and environmental effects.

LR 5.15.4.9 Conformance with the performance criteria, together with any specific requirements of the applicable Rules, standards and legislation is to be demonstrated by the designer/Builder and Owner/Operator to the satisfaction of LR.

LR 5.15.4.10 Where LR is acting on behalf of the Flag Authority, any relevant requirements of the Flag Authority are to be identified and advised to LR.

LR 5.15.5 Plans and particulars

LR 5.15.5.1 Plans, together with the relevant information as detailed in this Section, are to be submitted for consideration. Any subsequent modifications are subject to approval before being put into operation.

LR 5.15.5.2 Any alterations to basic design, construction, materials, manufacturing procedure, equipment, fittings or arrangements of the liquid gas transfer system are to be re-submitted for approval.

LR 5.15.5.3 A design statement of the liquefied gas transfer systems that details the capability and functionality under defined operating and emergency conditions. The design statement is to be agreed between the designers and Owners/Operators.

LR 5.15.5.4 **Lifting appliances.** Plans and details of all lifting appliances as required by LR's *Code for Lifting Appliances in a Marine Environment* or other specified design code to be submitted.

LR 5.15.5.5 **Piping plans.** Arrangements of loading/offloading system to be submitted for appraisal.

LR 5.15.6 Materials

LR 5.15.6.1 The materials used in the construction are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and of Chapter 6 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bu*lk (hereinafter referred to as Rules for Ships for Liquefied Gases), as applicable. Materials for which provision is not made in those requirements may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

LR 5.15.6.2 Materials of construction are to be suitable for the intended service, having regard to the substances, process and temperatures involved.

LR 5.15.6.3 Details of the materials proposed for all types of construction are to be submitted for approval.

LR 5.15.7 Liquefied gas transfer system

LR 5.15.7.1 Operating requirement(s) associated with liquefied gas transfer are to meet the requirements of Chapter 18 of the Rules for Ships for Liquefied Gases.

LR 5.15.7.2 Cargo transfer is usually accomplished by the use of hose(s) or loading arms (hard arms).

LR 5.15.7.3 All piping, valves and fittings are to be suitable for the design operating and environmental conditions.

LR 5.15.7.4 The piping is to comply with the requirements for manufacture, testing and certification of Class II piping systems.

LR 5.15.8 Transfer hose

LR 5.15.8.1 There are three types of cargo hoses suitable for liquefied gases transfer. These can be:

Composite.
Rubber.
Stainless steel construction.

LR 5.15.8.2. Liquid and vapour hoses used for liquefied gas transfer should be compatible with the cargo and suitable for the cargo temperature. The design, construction and testing of such hoses are to be to a suitable national standard such as BS ISO 4089 or BS ISO 5842. For hoses carried on board ship refer to the Rules for Ships for Liquefied Gases.

LR 5.15.8.3 Each transfer hose should be permanently marked with the following information and be compliant with the requirements of EN 1474 and other applicable Regulations, such as IMO's International Gas Code:

Hose serial number;
Internal diameter of the hose;
Overall weight of complete hose;
Date of manufacture;
Date of proof pressure testing;
Certifying authority stamp;
The maximum and minimum allowable working temperature range.

LR 5.15.8.4 The hose vendor should provide the following documents:

Hose certificate.
Hose quantity assurance manual.
Inspection, test and storage plan.
Operating manual.
Hose handling manual.

LR 5.15.8.5 Hoses of all types must be supported in a hose cradle or saddle to ensure that the manufacturer's recommendations on minimum bending radius are met. These supports may be integral to the load restraint system, preventing excessive axial and torsional loads on the cargo hose end fittings. Their design load and security should be considered, along with their ability to prevent chafing of the hoses(s) and their ability to avoid damage to handrails and other fittings in the event of a separation of the ERC. Their design should ensure electrical isolation is maintained between the hose and the ship's structure.

LR 5.15.8.6 When selecting hose size and length, the manufacturer's recommendations should be followed to determine the maximum flow rate and other operating parameters. The maximum hose size will also be governed by the capabilities of the onboard lifting equipment and manifold construction.

LR 5.15.8.7 In determining the size and length of the hose(s) to be used, the following should be considered:

- Minimum allowable bend radius of the hose;
- Horizontal distance between the vessels;
- Difference in fore and aft alignment (manifold offset);
- Distance between the manifold and the ship's side;
- Vertical and horizontal vessel movement;
- Any other special characteristics related to the vessels;
- Relative change in freeboard between the vessels;
- Flange connections minimised and accessible;
- Allowable flow velocity;
- Allowable pressure drop;
- Hose handling requirements and limitations of the equipment on board the offshore unit.

LR 5.15.8.8 The liquefied gas transfer equipment should be supported by suitable means to prevent excessive loads on manifold fittings, in accordance with OCIMF/SIGTTO manifold guidelines.

LR 5.15.9 Hard arm

LR 5.15.9.1 Where hard arms are considered for use in liquefied gas transfer operations, the following should be taken into account:

- Accelerations;
- Permissible manifold loadings;
- Arm working envelope;
- Arm support arrangement;
- Arm stowage arrangement;
- The effect of vibration on the arm;
- Maintenance requirements;
- Size of the arm;
- Connectability;
- Vertical and horizontal vessel movement;
- Allowable flow velocity and pressure loss;
- Testing requirements.

LR 5.15.9.2 Inserting an insulating flange in the lower end of the outer hard arm.

LR 5.15.9.3 The range of the operating envelope of the hard arm is to be determined by the perceived tidal variations and change of the freeboard between the offshore unit and receiving tanker whilst loading or discharge.

LR 5.15.9.4 The hard arm is to be provided with an emergency release system to provide a means to quickly uncouple the hard arms with minimum spillage in an emergency.

LR 5.15.9.5 The physical disconnection may be achieved by means of a powered emergency release coupler.

LR 5.15.9.6 The valve closure time should be such as to avoid surge pressure in pipelines. Such valves should close in such a manner as to cut off the flows smoothly.

Section

6.1 Definitions

6.1.1 Where reference is made in this Chapter to Grades A, B, D, E, AH, DH, EH and FH hull structural steels, these steel grades are hull structural steels according to the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

6.1.2 **A piece** is the rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.

6.1.3 **A batch** is the number of items or pieces to be accepted or rejected together, on the basis of the tests to be carried out on a sampling basis. The size of a batch is given in the recognised Standards.

6.1.4 **Accelerated Cooling (AcC)** is a process that aims to improve mechanical properties by controlled cooling with rates higher than air cooling, immediately after the final TMCP operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TMCP and AcC cannot be reproduced by subsequent normalising or other heat treatment.

6.1.5 **Controlled Rolling (CR)**, also known as **Normalising Rolling (NR)**, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

LR 6.1.1 **Normalising (N)** refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

LR 6.1.2 **Quenching and Tempering (QT)** is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

6.1.6 **Thermo-Mechanical Controlled Processing (TMCP)** is a procedure that involves strict control of both the steel temperature and the rolling reduction. Unlike CR, the properties conferred by TMCP cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TMCP may also be accepted subject to approval by the Administration. The same applies for the use of tempering after completion of the TMCP.

6.2 Scope and general requirement

6.2.1 This Chapter gives the requirements for metallic and non-metallic materials used in the construction of the cargo system. This includes requirements for joining processes, production process, personnel qualification, NDT and inspection and testing including production testing. The requirements for rolled materials, forgings and castings are given in 6.4 and Tables 6.1, 6.2, 6.3, 6.4 and 6.5. The requirements for weldments are given in 6.5 and the guidance for non metallic materials is given in Appendix 1. A quality assurance/quality control (QA/QC) program shall be implemented to ensure the requirements of 6.2.1 are complied with.

6.2.2 The manufacture, testing, inspection and documentation shall be in accordance with the requirements of this Chapter and the Rules for Materials. Testing and inspection to other recognised Standards will be subject to special agreement.

6.2.3 Where post-weld heat treatment is specified or required, the properties of the base materials, weld and heat affected zone shall be determined in the heat treated condition, in accordance with the requirements specified in this Chapter. Alternative arrangements for Charpy V-notch impact test temperature following post-weld heat treatment will be subject to special consideration.

6.3 General test requirements and specifications

LR 6.3.1 All mechanical tests required by this Chapter shall be carried out in accordance with the Rules for Materials.

LR 6.3.2 Acceptance tests for metallic materials shall include Charpy V-notch impact tests unless specified otherwise; the largest specimen possible for the material thickness should be machined. Requirements for testing specimens smaller than 5,0 mm in size shall be in accordance with recognised Standards.

LR 6.3.3 The bend test may be omitted as a material acceptance test, but is required for weld tests.

6.4 Requirements for metallic materials

6.4.1 General requirements for metallic materials

6.4.1.1 The requirements for materials of construction are shown in the Tables as follows:

Table 6.1: Plates, pipes (seamless and welded), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C.

Table 6.2: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to –55°C.

Table 6.3: Plates, sections and forgings for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to –165°C.

Table 6.4: Pipes (seamless and welded), forgings and castings for cargo and process piping for design temperatures below 0°C and down to –165°C.

Table 6.5: Plates and sections for hull structures required by 4.19.1.2 and 4.19.1.3.

LR 6.4.1 The material grades for the construction of the hull structure are to comply with the requirements of Table 2.4.1 in Pt 4, Ch 2 unless the minimum metal temperature is the result of heat conduction from the cargo, in which case hull materials shall be in accordance with Table 6.5.

LR 6.4.2 The sheerstrake is to be of Grade E/EH steel for ship units storing and offloading liquefied gases in bulk.

Table 6.1 Plates, pipes (seamless and welded, *see* Notes 1 and 2), sections and forgings for cargo tanks and process pressure vessels for design temperatures not lower than 0°C

Chemical composition and heat treatment	
• Carbon-manganese steel • Fully killed fine grain steel • Small additions of alloying elements by agreement with LR • Composition limits to be approved by LR • Normalised, quenched and tempered, *see* Note 4	
Tensile and toughness (impact) test requirements	
Sampling frequency	
• Plates	Each ‘piece’ to be tested
• Sections and forgings	Each ‘batch’ to be tested
Mechanical properties	
• Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2, *see* Note 5
Toughness (Charpy V-notch test)	
• Plates	Transverse test pieces. Minimum average value (*KV*) 27J
• Sections and forgings	Longitudinal test pieces. Minimum average energy (*KV*) 41J
• Test temperature •	Thickness *t* (mm) — Test temperature (°C) $t \leq 20$ — 0 $20 < t \leq 40$, *see* Note 3 — –20

NOTES
1. For seamless pipes and fittings, normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by LR.
2. Charpy V-notch impact tests are not required for pipes where the thickness is less than 15 mm.
3. This Table is generally applicable for material thicknesses up to 40 mm. Proposals for greater thicknesses shall be approved by LR.
4. A controlled rolling (normalising rolling) procedure may be used as an alternative. In addition, TCMP steel may be used as an alternative in applications where post-weld heat treatment is not required.
5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by LR. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Table 6.2 Plates, sections and forgings (*see* Note 1) for cargo tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to –55°C, maximum thickness 25 mm (*see* Note 2)

Chemical composition and heat treatment	

- Carbon-manganese steel
- Fully killed, aluminium treated fine grain steel
- Chemical composition (ladle analysis)

C	Mn	Si	S	P
0,16% max. *see* Note 3	0,70-1,60%	0,10-0,50%	0,025% max.	0,025% max.

Optional additions: Alloys and grain refining elements may be generally in accordance with the following:

Ni	Cr	Mo	Cu	Nb	V
0,80% max.	0,25% max.	0,08% max.	0,35% max.	0,05% max.	0,10% max.

Al content total 0,020% min. (acid soluble 0,015% min.)

- Normalised, or quenched and tempered, *see* Note 4

Tensile and toughness (impact) test requirements	
Sampling frequency	
• Plates	Each 'piece' to be tested
• Sections and forgings	Each 'batch' to be tested
Mechanical properties	
• Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2, *see* Note 5
Toughness (Charpy V-notch test)	
• Plates	Transverse test pieces. Minimum average energy value (*KV*) 27J
• Sections and forgings	Longitudinal test pieces. Minimum average energy (*KV*) 41J
• Test temperature	5°C below the design temperature or –20°C, whichever is lower

NOTES
1. The Charpy V-notch and chemistry requirements for forgings may be specially considered by LR.
2. For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below design temperature or –20°C, whichever is lower
$30 < t \leq 35$	15°C below design temperature or –20°C, whichever is lower
$35 < t \leq 40$	20°C below design temperature
$40 < t$	Temperature approved by LR

The impact energy value shall be in accordance with the Table for the applicable type of test specimen.
Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or –20°C, whichever is lower.
For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank shell thickness.
3. By special agreement with LR, the carbon content may be increased to 0,18% maximum provided the design temperature is not lower than –40°C.
4. A controlled rolling (normalising rolling) procedure may be used as an alternative. In addition, TMCP steel may be used as an alternative in applications where post-weld heat treatment is not required.
5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by LR. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Guidance
For materials exceeding 25 mm in thickness for which the test temperature is –60°C or lower, the application of specially treated steels or steels in accordance with Table 6.3 may be necessary.

Table 6.3 **Plates, sections and forgings (*see* Note 1) for cargo tanks, secondary barriers and process pressure vessels for design temperatures below –55°C and down to –165°C (*see* Note 2), maximum thickness 25 mm (*see* Notes 3 and 4)**

Minimum design temperature	Chemical composition, *see* Note 5, and heat treatment	Impact test temperature (°C)
–60	1,5% nickel steel – normalised or normalised and tempered or quenched and tempered or TMCP, *see* Note 6	–65
–65	2,25% nickel steel – normalised or normalised and tempered or quenched and tempered or TMCP, *see* Notes 6 and 7	–70
–90	3,5% nickel steel – normalised or normalised and tempered or quenched and tempered or TMCP, *see* Notes 6 and 7	–95
–105	5% nickel steel – normalised or normalised and tempered or quenched and tempered, *see* Notes 6, 7 and 8	–110
–165	9% nickel steel – double normalised and tempered or quenched and tempered, *see* Note 6	–196
–165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated, *see* Note 9	–196
–165	Aluminium alloys; such as type 5083 annealed	Not required
–165	Austenitic Fe-Ni alloy (36% nickel) heat treatment as agreed	Not required

Tensile and toughness (impact) test requirements	
Sampling frequency	
• Plates	Each ‘piece’ to be tested
• Sections and forgings	Each ‘batch’ to be tested
Toughness (Charpy V-notch test)	
• Plates	Transverse test pieces. Minimum average energy value (KV) 27J
• Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J

NOTES

1. The impact test required for forgings used in critical applications shall be subject to special consideration by LR.
2. The requirements for design temperatures below –165°C shall be specially agreed with LR.
3. For materials 1,5% Ni, 2,25% Ni, 3,5% Ni and 5% Ni, with thicknesses greater than 25 mm, the impact tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below design temperature
$30 < t \leq 35$	15°C below design temperature
$35 < t \leq 40$	20°C below design temperature

   The energy value shall be in accordance with the Table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values shall be specially considered.
4. For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.
5. The chemical composition limits shall be in accordance with Ch 3,6 of the Rules for Materials.
6. TMCP nickel steels will be subject to acceptance by LR.
7. A lower minimum design temperature for quenched and tempered steels may be specially agreed with LR.
8. A specially heat treated 5% nickel steel, for example, triple heat treated 5% nickel steel, may be used down to –165°C, provided that the impact tests are carried out at –196°C.
9. The impact test may be omitted subject to agreement with LR.

Table 6.4 **Pipes (seamless and welded, *see* Note 1), forgings and castings (*see* Note 2) for cargo and process piping for design temperatures below 0°C and down to –165°C (*see* Note 3), maximum thickness 25 mm**

Minimum design temperature	Chemical composition, *see* Note 5, and heat treatment	Impact test	
		Test temp. (°C)	Minimum average energy (KV)
–55	Carbon-manganese steel. Fully killed fine grain. Normalised or as agreed, *see* Note 6	*See* Note 4	27
–65	2.25% nickel steel. Normalised, normalised and tempered or quenched and tempered, *see* Note 6	–70	34
–90	3.5% nickel steel. Normalised, normalised and tempered or quenched and tempered, *see* Note 6	–95	34
–165	9% nickel steel, *see* Note 7. Double normalised and tempered or quenched and tempered	–196	41
–165	Austenitic steels, such as types 304. 304L, 316, 316L, 321 and 347. Solution treated, *see* Note 8	–196	41
–165	Aluminium alloys, such as type 5083 annealed		Not required
Tensile and toughness (impact) test requirements			
Sampling frequency			
• Each 'batch' to be tested.			
Toughness (Charpy V-notch test)			
• Impact test: longitudinal test pieces			

NOTES
1. The use of longitudinally or spirally welded pipes shall be specially approved by LR.
2. The requirements for forgings and castings may be subject to special consideration by LR.
3. The requirements for design temperatures below –165°C shall be specially agreed with LR.
4. The test temperature shall be 5°C below the design temperature or –20°C whichever is lower.
5. The composition limits shall be in accordance with Ch 6,4 of the Rules for Materials.
6. A lower design temperature may be specially agreed with LR for quenched and tempered materials.
7. This chemical composition is not suitable for castings.
8. Impact tests may be omitted subject to agreement with LR.

Table 6.5 **Plates and sections for hull structures required by 4.19.1.2 and 4.19.1.3**

Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above, *see* Note 1 –5 and above, *see* Note 2	To comply with Pt 10, Ch 1,3							
down to –5	15	25	30	50	25	45	50	50
down to –10	x	20	25	50	20	40	50	50
down to –20	x	x	20	50	x	30	50	50
down to –30	x	x	x	40	x	20	40	50
Below –30	In accordance with Table 6.2, except that the thickness limitation given in Table 6.2 and in Note 2 of that Table does not apply							

NOTES
'x' means steel grade not to be used.
1. For the purpose of 4.19.1.3.
2. For the purpose of 4.19.1.2.

6.5 Welding of metallic materials and non-destructive testing

6.5.1 **General**

6.5.1.1 This Section shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may be adapted for other materials. At the discretion of LR, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

6.5.2 **Welding consumables**

6.5.2.1 Consumables for welding of cargo tanks shall be in accordance with Chapter 11 of the Rules for Materials and recognised Standards.

6.5.3 **Welding procedure tests for cargo tanks and process pressure vessels**

6.5.3.1 Welding procedure tests for cargo tanks, secondary barriers, process pressure vessels and pressure pipework are to be qualified in accordance with Chapter 12 of the Rules for Materials.

LR 6.6 Specific welding requirements for liquefied petroleum gas and liquefied natural gas systems

LR 6.6.1 Scope

LR 6.6.1.1 The requirements of this Section apply to welding of cargo tanks, storage tanks, containment systems, process pressure vessels and pressure piping for liquefied natural gas systems.

LR 6.6.1.2 The requirements of this Section include the welding of carbon, carbon-manganese, nickel alloy, austenitic stainless steels and aluminium alloys specified in the Rules for Materials, as suitable for use in low temperature service.

LR 6.6.1.3 The requirements of this Section are in addition to those requirements specified in Chapter 13, Sections 1, 4 and 5 of the Rules for Materials.

LR 6.6.2 Welding qualifications
All welding procedures used during construction are to be qualified in accordance with the requirements specified in Chapter 12 of the Rules for Materials for liquid gas applications.

LR 6.6.3 Production weld test frequency

LR 6.6.3.1 For cargo tanks and process pressure vessels, except integral and membrane tanks, production weld tests shall be performed for each 50 m of butt weld joint and should be representative of each welding procedure and position used in construction.

LR 6.6.3.2 Production tests are required for secondary barriers but the number of tests required may be reduced to 1 in every 100 m of butt weld.

LR 6.6.3.3 Requirements for production testing of integral and membrane tanks are to be agreed with LR prior to manufacture.

LR 6.6.4 Production weld testing requirements

LR 6.6.4.1 The type and number of specimens to be removed from each test plate for mechanical testing shall be as specified for the original welding procedure qualification test, except that:

(a) the all weld tensile test may be omitted; and
(b) the number of impact tests from the heat affected zone may be reduced to sampling the location that demonstrated the lowest impact energy during procedure qualification.

LR 6.6.4.2 For independent tanks, Types A and B, the transverse tensile tests may also be omitted.

LR 6.6.4.3 The results of the mechanical tests are to meet the minimum requirements specified for the original welding procedure qualification test as specified in Chapter 12 of the Rules for Materials.

LR 6.6.4.4 Should any impact test fail to meet requirements, consideration will be given to acceptance based on satisfactory results from two drop weight tests from the failed location. The test temperature for these shall be no higher that that specified for the impact tests and the acceptance criteria for both tests shall be no break.

LR 6.6.5 Non-destructive examination

LR 6.6.5.1 All welds are to be subject to non-destructive examination in accordance with requirements specified in Chapter 13, Sections 4 and 5 of the Rules for Materials unless more stringent requirements are specified below.

LR 6.6.5.2 Radiographic examination may be substituted by ultrasonic examination, *see* Ch 13,4.15 of the Rules for Materials. In addition, ultrasonic examination may be used to augment radiographic testing for complex or critical welds.

LR 6.6.5.3 **Type A independent and semi-membrane tanks**:

(a) where the minimum design temperature is less than or equal to –20°C, the extent and type of testing shall be as for Type B tanks in LR 6.6.5.4.
(b) where the minimum design temperature is greater than –20°C, the extent and type of testing shall include 100 per cent volumetric examination of butt weld intersections, plus 10 per cent of other butt welds.
(c) the remaining tank structure shall be subject to crack detection examination in accordance with recognised standards and the extent of examination is to be agreed with LR.

LR 6.6.5.4 Type B independent tanks:
Irrespective of design temperature, all full penetration butt welds will be subject to 100 per cent volumetric examination. Other welds shall be subject to crack detection examination in accordance with recognised Standards and the extent of examination is to be agreed with LR.

LR 6.6.5.5 Type C independent tanks and process pressure vessels:
The extent of examination is dependent on the design conditions. Where the design incorporates a joint factor greater than 0,85, all butt welds will be subject to 100 per cent volumetric examination plus 10 per cent surface crack detection. Where the weld joint factor is less than or equal to 0,85, partial inspection may be considered. However, this should not be less than 10 per cent volumetric examination of full penetration butt welds, and 100 per cent surface crack detection of nozzle reinforcing rings and other vessel openings.

LR 6.6.5.6 Integral and membrane tanks:
Inspection is to be in accordance with recognised Standards and the extent and type of inspection is to be agreed with LR.

LR 6.6.5.7 Secondary barrier:
Where the outer shell of the hull is part of the secondary barrier, all sheerstrake butt welds and the intersections of all butt and seam welds in the side shell shall be examined volumetrically. The extent of inspections is to be agreed with LR.

LR 6.6.5.8 Inner hull and independent tank structures supporting internal insulation tanks:
Inspection requirements are to be in accordance with recognised Standards and are to be agreed with LR.

LR 6.6.5.9 Piping:
(a) for piping systems with design temperatures lower than –10°C and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm, piping shall be subject to 100 per cent radiographic inspection of butt-welded joints;
(b) for butt-welded joints made using fully automatic welding procedures during pipe shop fabrication, the extent of radiographic inspection may be progressively reduced by special agreement with LR. In no case will this be reduced below 10 per cent of joints. If defects are revealed the extent of examination shall be increased to 100 per cent and will include inspection of previously accepted welds. This special approval will only be granted where the fabricator has a well-documented quality assurance system that is working effectively and will be subject to audit by LR;
(c) for other butt-welded joints, spot radiography or other non-destructive tests shall be carried out depending on the service, position and materials. In general, at least 10 per cent of butt-welded joints of pipes should be radiographed. The extent of examination is to be agreed with LR.

6.7 Non-metallic materials

6.7.1 General

The information in the attached Appendix 1 is given for guidance in the selection and use of these materials, based on the experience to date.

Section

7.1 Methods of control

7.1.1 With the exception of tanks designed to withstand full gauge vapour pressure of the cargo under conditions of the upper ambient design temperatures, cargo tanks' pressure and temperature shall be maintained at all times within their design range by either one, or a combination of, the following methods:

.1 reliquefaction of cargo vapours
.2 thermal oxidation of vapours
.3 pressure accumulation
.4 liquid cargo cooling.

7.1.2 Venting of the cargo to maintain cargo tank pressure and temperature is not acceptable except in emergency situations. The Administration may permit certain cargoes to be controlled by venting cargo vapours to the atmosphere at sea.

7.2 Design of systems

LR 7.2.1 Details of the proposed system of cargo pressure/temperature control are to be submitted for consideration.
The ambient temperatures for air and sea-water are to be taken at their highest daily mean temperatures for the unit's proposed area of operation based on the 100 year average return period. The ambient temperatures are to be rounded up to the nearest degree Celsius.
The ambient temperatures are not to be taken as less than 45°C for air and 32°C for sea-water unless agreed by LR.
The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.

LR 7.2.2 The system is to be tested at entry into service to prove its capability to maintain the class notation temperature and pressure.

7.3 Reliquefaction of cargo vapours

7.3.1 **General**
The reliquefaction system may be arranged in one of the following ways:

.1 A direct system where evaporated cargo is compressed, condensed and returned to the cargo tanks.
.2 An indirect system where cargo or evaporated cargo is cooled or condensed by refrigerant without being compressed.
.3 A combined system where evaporated cargo is compressed and condensed in a cargo/refrigerant heat exchanger and returned to the cargo tanks.
.4 If the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases, as far as reasonably practicable, are disposed of without venting to atmosphere.

7.3.2 **Compatibility**
Refrigerants used for reliquefaction shall be compatible with the cargo they may come into contact with.
In addition, when several refrigerants are used and may come into contact, they shall be compatible with each other.

7.4 Thermal oxidation of vapours

The use of thermal oxidation equipment on ship units engaged in the production, storage and offloading of liquefied gases in bulk at a fixed location is not anticipated, in the event that this or similar equipment is used it is to comply with Lloyd's Register's *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

7.5 Pressure accumulation systems

The containment system insulation, design pressure or both shall be adequate to provide for a suitable margin for the operating time and temperatures involved. No additional pressure and temperature control system is required.

7.6 Liquid cargo cooling

The bulk cargo liquid may be refrigerated by coolant circulated through coils fitted either inside the cargo tank or onto the external surface of the cargo tank.

7.7 Segregation

Where two or more cargoes that may react chemically in a dangerous manner are carried simultaneously, separate systems as defined in 1.2, each complying with availability criteria as specified in 7.8, shall be provided for each cargo. For simultaneous carriage of two or more cargoes that are not reactive to each other but where, due to properties of their vapour, separate systems are necessary, separation may be by means of isolation valves.

7.8 Availability

The availability of the system and its supporting auxiliary services shall be such that:

.1 In case of a single failure of a mechanical non-static component or a component of the control systems, the cargo tanks' pressure and temperature can be maintained within their design range without affecting other essential services.

.2 Redundant piping systems are not required.

.3 Heat exchangers that are solely necessary for maintaining the pressure and temperature of the cargo tanks within their design ranges shall have a stand-by heat exchanger unless they have a capacity in excess of 25 per cent of the largest required capacity for pressure control and they can be repaired onboard without external resources. Where an additional and separate method of cargo tank pressure and temperature control is fitted that is not reliant on the sole heat exchanger, then a standby heat exchanger is not required.

.4 For any cargo heating or cooling medium, provisions shall be made to detect the leakage of toxic or flammable vapours into an otherwise non-hazardous area or overboard in accordance with 13.6. Any vent outlet from this leak detection arrangement shall be to a non-hazardous area and be fitted with a flame screen.

LR 7.8.1 It is recommended that a reasonable margin in plant output over maximum load be allowed for possible overall inefficiencies under service conditions. It is also recommended that due regard be given to any additional capacity required to deal with cargo loading conditions.

LR 7.8.2 It is recommended that adequate spares, together with the tools necessary for maintenance, or repair, be carried. The spares are to be determined by the Owner according to the design and intended service. The maintenance of the spares is the responsibility of the Owner.

Section

8.1 General

All cargo tanks shall be provided with a pressure relief system appropriate to the design of the cargo containment system and the cargo being carried. Hold space and interbarrier spaces, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in Chapter 7 shall be independent of the pressure relief systems.

8.2 Pressure relief systems

8.2.1 Cargo tanks, including deck tanks, are to be fitted with a minimum of two Pressure Relief Valves (PRVs) each being of equal size within manufacturer's tolerances and suitably designed and constructed for the prescribed service.

8.2.2 Interbarrier spaces shall be provided with pressure relief devices. Reference is made to IACS Unified Interpretation *GC9 Guidance for sizing pressure relief systems for interbarrier spaces 1988.* For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs.

8.2.3 The setting of the PRVs shall not be higher than the vapour pressure that has been used in the design of the tank. Where two or more PRVs are fitted, valves comprising not more than 50 per cent of the total relieving capacity may be set at a pressure up to 5 per cent above MARVS to allow sequential lifting, minimising unnecessary release of vapour.

8.2.4 The following temperature requirements apply to PRVs fitted to pressure relief systems:

.1 PRVs on cargo tanks with a design temperature below 0°C shall be designed and arranged to prevent their becoming inoperative due to ice formation.

.2 The effects of ice formation due to ambient temperatures shall be considered in the construction and arrangement of PRVs.

.3 PRVs shall be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised.

.4 Sensing and exhaust lines on pilot operated relief valves shall be of suitably robust construction to prevent damage.

8.2.5 **Valve testing**

PRVs shall be tested in accordance with a Recognised Standard or equivalent national standards. Reference is made to:
ISO 21013-1 2008 – *Cryogenic vessels – Pressure-relief accessories for cryogenic service – Part 1: Reclosable pressure-relief valves*; and
ISO 4126-1; 2004 *Safety devices for protection against excessive pressure – Part 1 and part 4: Safety valves*.

8.2.5.1 PRVs shall be type tested. Type tests shall include:

.1 verification of relieving capacity.

.2 cryogenic testing when operating at design temperatures colder than –55°C.

.3 seat tightness testing.

.4 pressure containing parts are to be pressure tested to at least 1,5 times the design pressure.

8.2.5.2 Each PRV shall be tested to ensure that:

.1 it opens at the prescribed pressure setting, with an allowance not exceeding ±10 per cent for 0 to 0,15 MPa, ±6 per cent for 0,15 to 0,3 MPa, ±3 per cent for 0,3 MPa and above.

.2 seat tightness is acceptable.

.3 pressure containing parts are to withstand at least 1,5 times the design pressure.

LR 8.2.1 As soon as practicable prior to proceeding on gas trials, pressure relief valves are to be tested and installed in accordance with the manufacturer's recommended procedures to the Surveyor's satisfaction. Where valves are stored prior to installation on board, the storage arrangements are also to be in accordance with the manufacturer's recommended procedures.

8.2.6 PRVs shall be set and sealed by the Administration or recognised organisation acting on its behalf and a record of this action, including the valves' set pressure, shall be retained onboard the ship unit.

8.2.7 Cargo tanks may be permitted to have more than one relief valve set pressure in the following cases:

.1 installing two or more properly set and sealed PRVs and providing means as necessary for isolating the valves not in use from the cargo tank; or

.2 installing relief valves whose settings may be changed by the use of a previously approved device not requiring pressure testing to verify the new set pressure. All other valve adjustments shall be sealed.

8.2.8 Changing the set pressure under the provisions of 8.2.7, and the corresponding resetting of the alarms referred to in 13.4.2, shall be carried out under the supervision of the Master in accordance with approved procedures and as specified in the operating manual of the ship unit. Changes in set pressure shall be recorded in the ship unit's log and a sign shall be posted in the cargo control room if provided, in the main control area if separate from the cargo control room, and at each relief valve, stating the set pressure.

8.2.9 In the event of a failure of a cargo tank PRV a safe means of emergency isolation shall be available.

.1 Procedures are to be provided and included in the cargo operations manual (*see* 18.2).

.2 The procedures shall allow only one of the cargo tank's installed PRVs to be isolated.

.3 Isolation of the PRV shall be carried out under the supervision of the Master. This action shall be recorded in the ship unit's log and a sign posted in the cargo control room, if provided, and at the PRV.

.4 The tank shall not be loaded until the full relieving capacity is restored.

8.2.10 Each PRV installed on a cargo tank shall be connected to a venting system, which shall be:

.1 so constructed that the discharge will be unimpeded and directed vertically upwards at the exit.

.2 arranged to minimise the possibility of water or snow entering the vent system.

.3 arranged such that the height of vent exits shall not be less than *B*/3 or 6 m, whichever is the greater, above the weather deck.

.4 6 m above working areas and walkways.

8.2.11 Cargo PRV vent exits shall be arranged at a distance at least equal to *B* or 25 m, whichever is less, from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.

.1 All other vent outlets connected to the cargo containment system shall be arranged at a distance of at least 10 m from the nearest air intake, outlet or opening to accommodation spaces, service spaces and control stations, or other non-hazardous areas.

8.2.12 All other cargo vent outlets not dealt with in other chapters shall be arranged in accordance with 8.2.10 and 8.2.11. Means shall be provided to prevent liquid overflow from vent mast outlets, due to hydrostatic pressure from spaces to which they are connected.

8.2.13 If cargoes that react in a dangerous manner with each other are carried simultaneously, a separate pressure relief system shall be fitted for each one.

8.2.14 In the vent piping system, means for draining liquid from places where it may accumulate shall be provided. The PRVs and piping shall be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

8.2.15 Suitable protection screens of not more than 13 mm square mesh shall be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow. Protective screens when storing pentane are also to comply with 17.2.

8.2.16 All vent piping shall be designed and arranged not to be damaged by; the temperature variations to which it may be exposed, forces due to flow or the motions of the ship unit.

8.2.17 PRVs shall be connected to the highest part of the cargo tank above deck level. PRVs shall be positioned on the cargo tank so that they will remain in the vapour phase at the filling limit (FL) as defined in Chapter 15, under conditions of 15° list and 0,015*L* trim, where *L* is defined in 1.2.

8.2.18 The adequacy of the vent system fitted on tanks loaded in accordance with 15.5.2, is to be demonstrated using the *Guidelines for the Evaluation of the Adequacy of Type C Tank Vent Systems*, IMO Resolution A.829(19). A relevant certificate shall be permanently kept onboard the ship unit. For the purposes of this paragraph, vent system means:

.1 the tank outlet and the piping to the PRV.

.2 the PRV.

.3 the piping from the PRVs to the location of discharge to the atmosphere, including any interconnections and piping that joins other tanks.

8.3 Vacuum protection systems

8.3.1 Cargo tanks not designed to withstand a maximum external pressure differential 0,025 MPa, or tanks that cannot withstand the maximum external pressure differential that can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, or by thermal oxidation, shall be fitted with:

.1 two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank and refrigeration equipment, if fitted, by suitable means at a pressure sufficiently below the maximum external designed pressure differential of the cargo tank; or

.2 vacuum relief valves with a gas flow capacity at least equal to the maximum cargo discharge rate per cargo tank, set to open at a pressure sufficiently below the external design differential pressure of the cargo tank.

8.3.2 Subject to the requirements of Chapter 17, the vacuum relief valves shall admit an inert gas, cargo vapour or air to the cargo tank and shall be arranged to minimise the possibility of the entrance of water or snow *see also* LR 8.3.1. If cargo vapour is admitted it shall be from a source other than the cargo vapour lines.

LR 8.3.1 Vacuum relief valves are not to admit air to the cargo tanks except where satisfactory controls, low pressure alarms and automatic devices for stopping cargo pumps and compressors, etc., are fitted and adjusted such that the pressure in the tanks cannot fall below a predetermined minimum safe level. Details are to be submitted for consideration.

8.3.3 The vacuum protection system shall be capable of being tested to ensure that it operates at the prescribed pressure.

8.4 Sizing of pressure relieving system

8.4.1 Sizing of pressure relief valves

PRVs shall have a combined relieving capacity for each cargo tank to discharge the greater of the following, with not more than a 20 per cent rise in cargo tank pressure above the MARVS:

.1 the maximum capacity of the cargo tank inerting system if the maximum attainable working pressure of the cargo tank inerting system exceeds the MARVS of the cargo tanks; or

.2 vapours generated under fire exposure computed using the following formula:

$$Q = FGA^{0,82} \text{ (m}^3\text{/s)}$$

where

Q = minimum required rate of discharge of air at standard conditions of 273,15 Kelvin (K) and 0,1013 MPa

F = fire exposure factor for different cargo types

F = 1,0 for tanks without insulation located on deck

F = 0,5 for tanks above the deck when insulation is approved by LR. (Approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure)

F = 0,5 for uninsulated independent tanks installed in holds

F = 0,2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds)

F = 0,1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds)

F = 0,1 for membrane and semi membrane tanks
For independent tanks partly protruding through the weather decks, the fire exposure factor shall be determined on the basis of the surface areas above and below deck

G = gas factor

$$G = \frac{12,4}{LD}\sqrt{\frac{ZT}{M}}$$

with

T = temperature in Kelvin at relieving conditions, i.e. 120 per cent of the pressure at which the pressure relief valve is set

L = latent heat of the material being vaporised at relieving conditions, in kJ/kg

D = a constant based on relation of specific heats k and is calculated as follows

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

k = ratio of specific heats at relieving conditions, and the value of which is between 1,0 and 2,2. If k is not known, D = 0,606 shall be used.

Z = compressibility factor of the gas at relieving conditions; if not known, Z = 1,0 shall be used.

M = molecular mass of the product.

The gas factor of each cargo to be carried shall be determined and the highest value shall be used for PRV sizing.

A = external surface area of the tank (m^2) for different tank types, as shown in Fig. 8.1:

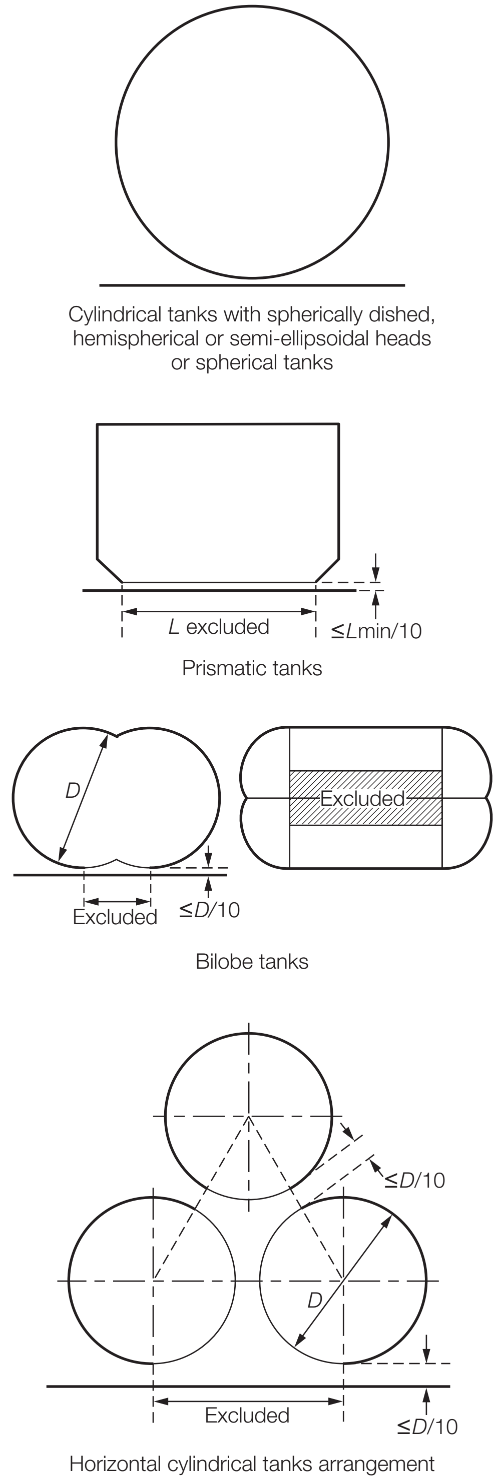


Fig. 8.1

8.4.1.3 The required mass flow of air at relieving conditions is given by:

$$M_{air} = Q\,\rho_{air} \text{ (kg/s)}$$

where:

Density of air (ρ_{air}) = 1,293 kg/m^3 (air at 273,15 K, 0,1013 MPa)

8.4.2 **Sizing of vent pipe system**

As in 5.2.1.4 and 5.6.4 the relief system is to be designed in accordance with API 521 *Guide for Pressure-relieving and Depressuring Systems: Petroleum petrochemical and natural gas industries – Pressure-relieving and depressuring systems*, taking into account the following.

8.4.2.1 Pressure losses upstream and downstream of the PRVs, shall be taken into account when determining their size to ensure the flow capacity required by 8.4.1.

8.4.3 **Upstream pressure losses**

8.4.3.1 The pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3 per cent of the valve set pressure at the calculated flow rate, in accordance with 8.4.1.

8.4.3.2 Pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome.

8.4.3.3 Pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots.

8.4.4 **Downstream pressure losses**

8.4.4.1 Where common vent headers and vent masts are fitted, calculations shall include flow from all attached PRVs.

8.4.4.2 The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe inter-connections that join other tanks, shall not exceed the following values:

- For unbalanced PRVs: 10 per cent of MARVS;
- For balanced PRVs: 30 per cent of MARVS;
- For pilot operated PRVs: 50 per cent of MARVS.

Alternative values provided by the PRV manufacturer may be accepted.

8.4.5 To ensure stable PRV operation, the blow-down shall not be less than the sum of the inlet pressure loss and 0,02 MARVS at the rated capacity.

9.1 Atmosphere control within the cargo containment system

9.1.1 A piping system shall be arranged to enable each cargo tank to be safely gas freed, and to be safely filled with cargo vapour from a gas free condition. The system shall be arranged to minimise the possibility of pockets of gas or air remaining after changing the atmosphere.

9.1.2 For flammable cargoes, the system shall be designed to eliminate the possibility of a flammable mixture existing in the cargo tank during any part of the atmosphere change operation by utilising an inerting medium as an intermediate step.

9.1.3 Piping systems that may contain flammable cargoes shall comply with 9.1.1 and 9.1.2.

9.1.4 A sufficient number of gas sampling points shall be provided for each cargo tank and cargo piping system to adequately monitor the progress of atmosphere change. Gas sampling connections shall be fitted with a single valve above the main deck, sealed with a suitable cap or blank. *See also* 5.6.5.5.

9.1.5 Inert gas utilised in these procedures is to be provided onboard the ship unit.

9.2 Atmosphere control within the hold spaces (cargo containment systems other than Type C independent tanks)

9.2.1 Interbarrier and hold spaces associated with cargo containment systems for flammable gases requiring full or partial secondary barriers shall be inerted with a suitable dry inert gas and kept inerted with make up gas provided by a shipboard inert gas generation system, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days.

9.2.2 Alternatively, subject to the restrictions specified in Chapter 17, the spaces referred to in 9.2.1 requiring only a partial secondary barrier may be filled with dry air provided that the ship unit maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the cargo tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided.

9.2.3 For non flammable gases, the spaces referred to in 9.2.1 and 9.2.2 may be maintained with a suitable dry air or inert atmosphere.

9.3 Environmental control of spaces surrounding Type C independent tanks

9.3.1 Spaces surrounding cargo tanks that do not have secondary barriers shall be filled with suitable dry inert gas or dry air and be maintained in this condition with make up inert gas provided by a shipboard inert gas generation system, shipboard storage of inert gas, or with dry air provided by suitable air drying equipment. If the cargo is carried at ambient temperature, the requirement for dry air or inert gas is not applicable.

9.4 Inerting

9.4.1 Inerting refers to the process of providing a non-combustible environment. Inert gases should be compatible chemically and operationally at all temperatures likely to occur within the spaces and the cargo. The dew points of the gases shall be taken into consideration.

9.4.2 Where inert gas is also stored for fire-fighting purposes it shall be carried in separate containers and shall not be used for cargo services.

9.4.3 Where inert gas is stored at temperatures below 0°C, either as a liquid or as a vapour, the storage and supply system shall be designed so that the temperature of the structure of the ship unit is not reduced below the limiting values imposed on it.

9.4.4 Arrangements to prevent the backflow of cargo vapour into the inert gas system that are suitable for the cargo carried, shall be provided. If such plants are located in machinery spaces or other spaces outside the cargo area, two non-return valves or equivalent devices and, in addition, a removable spool piece shall be fitted in the inert gas main in the cargo area. When not in use, the inert gas system shall be made separate from the cargo system in the cargo area except for connections to the hold spaces or interbarrier spaces.

9.4.5 The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc, shall be provided for controlling pressure in these spaces.

9.4.6 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual spaces.

LR 9.4.1 Inert gas systems are to be so designed as to minimise the risk of ignition from the generation of static electricity by the system itself.

9.5 Inert gas production on board

9.5.1 The equipment shall be capable of producing inert gas with an oxygen content at no time greater than 5 per cent by volume. A continuous reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5 per cent oxygen content by volume.

9.5.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the cargo containment system.

9.5.3 Spaces containing inert gas generation plants shall have no direct access to accommodation spaces, service spaces or control stations, but may be located in machinery spaces. Inert gas piping shall not pass through accommodation spaces, service spaces or control stations.

9.5.4 Combustion equipment for generating inert gas shall not be located within the cargo area. Special consideration may be given to the location of inert gas generating equipment using a catalytic combustion process.

Section

10.1 **General requirements**

10.2 **Definitions**

10.1 General requirements

LR 10.1.1 For the hull structure and associated liquefied gas cargo containment system, hazardous areas are to be determined, and electrical equipment is to be selected, in accordance with IEC 60092: *Electrical installations in ships – Part 502: Tankers - Special features*.
For topsides process facilities, the hazardous areas and electrical equipment selected for these areas should be established from suitable recognised hazardous area guidance, i.e., NFPA 497 *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas* or EI IP-MCSP-P15 *Model Code of Safe Practice Part 15 Area Classification Code for installations handling flammable fluids*. However, whichever Standard is selected for the classification of topsides process hazards, it should be ensured that it gives a suitably conservative determination of the defined hazardous area. Reference should also be made to the requirements stipulated within Pt 7, Ch 2.

10.1.1 Electrical installations shall be such as to minimise the risk of fire and explosion from flammable products.

10.1.2 Electrical installations shall be in accordance with recognised Standards. Reference is made to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999 Electrical installations in ships - Part 502: Tankers - Special features.

10.1.3 Electrical equipment or wiring should not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

10.1.4 Where electrical equipment is installed in hazardous areas as provided in 10.1.3 it shall be selected, installed and maintained in accordance with Standards not inferior to IEC 60092-502:1999 (*see* Clause 6, Clause 7 and Clause 9) Electrical installations in ships - Part 502: Tankers - Special features. Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognised by the Administration. Automatic isolation of non certified equipment on detection of a flammable gas shall not be accepted as an alternative to the use of certified equipment.

10.1.5 To facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones in accordance with recognised Standards.

10.1.6 Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain cargo tank pressures, as required by 7.8.1, and hull structure temperature, as required by 4.19.1, within normal operating limits. Failure modes and effects shall be analysed and documented to a standard not inferior to IEC 60812 Analysis techniques for system reliability Procedure for failure mode and effects analysis (FMEA).

10.1.7 The lighting system in hazardous areas shall be divided between at least two branch circuits. All switches and protective devices shall interrupt all poles or phases and shall be either:

(a) located in a non hazardous area; or
(b) certified for use in the hazardous area where installed in accordance with paragraph 6.5 of IEC 60092-502 Electrical installations in ships - Part 502: Tankers - Special features.

10.1.8 Electrical depth sounding or log devices and impressed current cathodic protection system anodes or electrodes shall be housed in gastight enclosures.

10.1.9 Submerged cargo pump motors and their supply cables may be fitted in cargo containment systems. Arrangements shall be made to automatically shut down the motors in the event of low liquid level. This may be accomplished by sensing low pump discharge pressure, low motor current, or low liquid level. This shutdown shall be alarmed at the cargo control station. Cargo pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.

LR 10.1.2 Electrical equipment that is located in either enclosed or open non hazardous areas and is to remain operational during catastrophic emergency conditions (i.e., major hydrocarbon release scenarios) is to be certified for operation in Zone 1 hazardous areas. However if such emergency equipment is not certified for operation in Zone 1 hazardous areas, the continued operation of this equipment maybe acceptable if it is demonstrated that the equipment is appropriately protected against potentially coming into contact with a flammable atmosphere by being located in an enclosed safe area, with appropriate mitigating measures (i.e. enclosed safe area is equipped with gas tight barriers, gas tight doors, rated gas dampers, suitable gas detection within the enclosure and its ventilation air intakes, etc.).

10.2 Definitions

For the purpose of this Chapter, unless expressly provided otherwise, the definitions below shall apply.

10.2.1 **Hazardous area** is an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

10.2.1.1 **Zone 0 hazardous area** is an area in which an explosive gas atmosphere is present continuously or is present for long periods.

10.2.1.2 **Zone 1 hazardous area** is an area in which an explosive gas atmosphere is likely to occur in normal operation.

10.2.1.3 **Zone 2 hazardous area** is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so infrequently and for a short period only.

10.2.2 **Non-hazardous area** is an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

LR 10.2.1 *See also* Pt 7, Ch 2,1.2.

Section

11.1 Fire safety requirements

LR 11.1.1 Fire prevention and fighting measures for the hull, hull weather deck and liquefied gas offloading facilities are generally to be in compliance with the following Sections, which reflect the requirements of the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code). However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy. The various requirements of Part 7 should also be fully referenced in connection with fire-fighting and fire mitigating measures.

11.1.1 In general, the requirements for tankers in SOLAS Chapter II-2 are to apply to ship units covered by this Part, irrespective of tonnage of the unit, with the exception of the following:

.1 regulations 4.5.1.6 and 4.5.10 do not apply;

.2 regulation 10.2 as applicable to cargo ships, and regulations 10.4 and 10.5 are in general to apply to the hull structure of the installation, as they would apply to tankers of 2000 gross tonnage and over;

.3 regulation 10.5.6 is to apply to the hull structure;

.4 the following regulations of SOLAS Chapter II-2 related to tankers do not apply and are replaced by the Chapters and Sections of this Part as detailed below:

Regulation	**Replaced by**
10.10	Part 11, 11.6
4.5.1.1 and 4.5.1.2	Part 11, Chapter 3
4.5.5 and 10.8	Part 11, 11.3 and 11.4
10.9	Part 11, 11.5
10.2	Part 11, 11.2.1 to 11.2.4

.5 regulations 13.3.4 and 13.4.3 shall apply to the ship unit.

LR 11.1.2 Emergency escape breathing devices, in addition to those required by 11.1.1.5, should be available as determined by the escape, evacuation and rescue analysis of the unit.

LR 11.1.3 For the hull structure of the unit, all sources of ignition should be excluded from spaces where flammable vapour may be present, except as otherwise provided in Chapter 10 and Chapter 16. For the topsides areas of the unit, sources of ignition should be minimised where practicable, but must always be certified for any defined hazardous area in which it is intended to operate. *See also* Pt 7, Ch 1 and 2 with regard to mitigation of ignition risks.

11.1.3 The provisions of this Section apply in conjunction with Chapter 3.

11.1.4 For the purposes of fire fighting, any weather deck areas above cofferdams, ballast or void spaces at the after end of the aftermost hold space or at the forward end of the forwardmost hold space shall be included in the cargo area.

11.2 Fire mains and hydrants

11.2.1 All ship units, irrespective of size, with bulk liquefied gas storage and/or vapour discharge and loading manifolds/facilities, carrying products specified in Chapter 19 are in general to comply with the requirements of SOLAS regulations II-2/10.2, except that the required fire pump capacity and fire main and water service pipe diameter should not be limited by the provisions of regulations II-2/10.2.2.4.1 and II-2/10.2.1.3. When a fire pump is used as part of the water spray system, as permitted by 11.3.3 of this Chapter, the capacity of this fire pump shall be such that these areas can be protected when simultaneously supplying two jets of water from fire hoses with 19 mm nozzles at a pressure of at least 5,0 bar gauge for hydrants located at hull, hull weather deck and liquefied gas offloading facilities. For hydrant located on topsides facilities, the pressure should be at least 3,5 bar gauge for two operational hydrants.

LR 11.2.1 In addition to 11.2.1, the fire pump capacity and fire main should be sized to supply all credible fire water demands associated with a credible installation fire scenario determined via the Fire and Explosion Evaluation (FEE).

11.2.2 The arrangements shall be such that at least two jets of water can reach any part of the deck in the cargo area, those portions of the cargo containment system and tank covers that are above the deck, and topside areas. The necessary number of fire hydrants shall be located to satisfy the above arrangements and to comply with the requirements of SOLAS regulations II-2/10.2.1.5.1 and II-2/10.2.3.3, taking into account the length of the hoses used at the location. The hose length should be 15 m in hull machinery spaces and should not be greater than 20 m in topsides areas, due to space constraints to enable the hose to be laid out by a fire team in a fire incident.

11.2.3 Stop valves shall be fitted in any crossover provided and in the fire main or mains in a protected location, before entering the cargo area and at intervals ensuring isolation of any damaged single section of the fire main, so that regulation 11.2.2 can be complied with using not more than two lengths of hoses from the nearest fire hydrant. The water supply to the fire main serving the cargo area shall be a ring main supplied by the main fire pumps or a single main supplied by fire pumps positioned outside the cargo area. The main installation firewater pumps are to be positioned to ensure a high degree of firewater pump redundancy and firewater supply integrity in potential major installation fire scenarios.

11.2.4 All nozzles provided for fire hoses shall be of an approved dual purpose type, capable of producing either a spray or a jet. All pipes, valves, nozzles and other fittings in the fire fighting systems shall be resistant to corrosion by sea water. Fixed piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925°C and remain functional.

11.2.5 After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

11.3 Water-spray system

11.3.1 A water application system, which may be based on water-spray nozzles, for cooling, fire prevention and crew protection shall be installed to cover:

.1 exposed cargo tank domes, any exposed parts of cargo tanks and any part of cargo tank covers that may be exposed to heat from fires in adjacent equipment containing cargo such as exposed booster pumps/heaters/re-gasification or re-liquefaction plants, hereafter addressed as gas process units, positioned on weather decks;

.2 exposed on-deck storage vessels for flammable or toxic products;

.3 gas process units, positioned on deck;

.4 cargo liquid and vapour discharge and loading connections, including the presentation flange and the area where their control valves are situated, which shall be at least equal to the area of the drip trays provided;

.5 all exposed emergency shut down (ESD) valves in the cargo liquid and vapour pipes, including the master valve for supply to gas consumers;

.6 exposed boundaries facing the cargo area, such as bulkheads of superstructures and deckhouses normally manned, cargo machinery spaces, store-rooms containing high fire risk items and cargo control rooms. Exposed horizontal boundaries of these areas do not require protection unless detachable cargo piping connections are arranged above or below. Boundaries of unmanned forecastle structures not containing high fire risk items or equipment do not require water-spray protection;

.7 any semi-enclosed cargo machinery spaces and semi-enclosed cargo motor room.

LR 11.3.1 Water spray fire-fighting measures for the hull, hull weather deck and liquefied gas offloading facilities are generally to be in compliance with the following Sections, which reflect the requirements of the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code). However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy. The various requirements of Part 7 should also be fully referenced in connection with fire-fighting and fire mitigating measures.

11.3.2 The system shall be capable of covering all areas mentioned in 11.3.1.1 to 11.3.1.8, with a uniformly distributed water application rate of at least 10 l/m^2/minute for the largest projected horizontal surfaces and 4 l/m^2/minute for vertical surfaces. For structures having no clearly defined horizontal or vertical surface, the capacity of the water application shall not be less than the projected horizontal surface multiplied by 10 l/m^2/minute.
On vertical surfaces, spacing of nozzles protecting lower areas may take account of anticipated rundown from higher areas. Stop valves shall be fitted in the spray water application main supply line(s), at intervals not exceeding 40 m, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position outside of the cargo area. A section protecting any area included in 11.3.1.1 and 11.3.1.2 shall cover at least the entire athwartship tank grouping in that area. Any gas process unit(s) included in 11.3.1.3 may be served by an independent section.

11.3.3 The capacity of the water application pumps shall be capable of simultaneous protection of any two complete athwartship tank groupings, including any gas process units within these areas in addition to surfaces specified in 11.3.1.4, 5, 6, 7 and 8. Alternatively, the main fire pumps may be used for this service provided that their total capacity is increased by the amount needed for the water-spray application system. In either case a connection, through a stop valve, shall be made between the fire main and water-spray application system main supply line outside of the cargo area. *See also* LR 11.2.1.

11.3.4 The maximum credible firewater demand should be determined in the installation Fire and Explosion Evaluation (FEE) based on the credible activation of water spray systems detailed in 11.3 and any additional topside module and hydrant demands.

LR 11.3.2 The installation main firewater pumps should be sized suitably to supply the defined maximum credible firewater demand. The installation design should incorporate a suitable allowance for firewater pump redundancy. This redundancy is to allow for failure of a firewater pump on demand or loss of a firewater pump for maintenance without incurring potential lost production on the installation due to the loss of firewater supply. Permanently manned hydrocarbon installations typically have two 100 per cent or three 50 per cent firewater pumps designed to meet the installation's defined largest credible firewater demand scenario (i.e., the installation's 100 per cent firewater

demand). However, other configurations of firewater pump supply redundancy may be acceptable for an installation, subject to suitable demonstration (for example, normally unmanned installations often do not have any dedicated fire-water pumps).

11.3.5 Water pumps normally used for other services may be arranged to supply the water-spray application system main supply line.

11.3.6 All pipes, valves, nozzles and other fittings in the water application systems shall be resistant to corrosion by seawater. Galvanised pipework may be considered for this service but copper nickel alloy or stainless steel pipework which is rated for marine/sea-water/fire-fighting service is recommended for installations. Piping, fittings and related components within the cargo area (except gaskets) shall be designed to withstand 925°C. The water application system shall be arranged with in-line filters to prevent blockage of pipes and nozzles. In addition means shall be provided to back flush the system with fresh water.

11.3.7 Remote starting of pumps supplying the water application system and remote operation of any normally closed valves in the system shall be arranged in suitable locations outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the protected areas.

11.3.8 After installation, the pipes, valves, fittings and assembled system shall be subject to a tightness and function test.

LR 11.3.3 The provision of fixed firewater fire-fighting facilities over topsides process module areas should be established based on the fire-fighting risks and philosophy derived for the installation via the Fire and Explosion Evaluation (FEE).

11.4 Dry chemical powder fire-extinguishing systems

LR 11.4.1 Dry chemical fire-fighting measures for the hull, hull weather deck and liquefied gas offloading facilities are generally to be in compliance with the following Sections, which reflect the requirements of the *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk* (IGC Code). However, alternative fire protection and fire mitigating measures may be considered to be appropriate following assessment via the installation Fire and Explosion Evaluation (FEE), dependent upon the installation's fire-fighting and safety philosophy. The various requirements of Part 7 should also be fully referenced in connection with fire-fighting and fire mitigating measures.

11.4.1 Dependent upon the conclusions of the Fire and Explosion Evaluation (FEE) and the installation's fire-fighting and safety philosophy, consideration for ship units should be given to the provision of fixed dry chemical powder fire-extinguishing systems, complying with the provisions of the FSS Code, for the purpose of fire-fighting on the deck in the cargo area, including all cargo liquid and vapour discharge and loading connections on deck and cargo handling areas as applicable.

11.4.2 The system shall be capable of delivering powder from at least two hand hose lines, or a combination of monitor/hand hose lines, to any part of the exposed cargo area, cargo liquid and vapour piping, load/unload connections and exposed gas process units.

11.4.3 The dry chemical powder fire-extinguishing system shall be designed with not less than two independent units. Any part required to be protected by 11.4.2 shall be capable of being reached from not less than two independent units with associated controls, pressurising medium fixed piping, monitors or hand hose lines. A monitor shall be arranged to protect any load/unload connection areas and be capable of actuation and discharge both locally and remotely. The monitor is not required to be remotely aimed if it can deliver the necessary powder to all required areas of coverage from a single position. One hose line shall be provided at both port and starboard side at the end of the cargo area facing the accommodation and readily available from the accommodation.

11.4.4 A fire-extinguishing unit having two or more monitors, hand hose lines, or combinations thereof, should have independent pipes with a manifold at the powder container, unless alternative means are provided, with a level of performance acceptable to LR. Where two or more pipes are attached to a unit the arrangement should be such that any or all of the monitors and hand hose lines should be capable of simultaneous or sequential operation at their rated capacities. The components associated with the dry chemical powder fire-extinguishing system(s) are to be in accordance with an acceptable national or international standard, and be of an approved type where appropriate.

11.4.5 The capacity of a monitor shall be not less than 10 kg/s. Hand hose lines shall be non-kinkable and be fitted with a nozzle capable of on/off operation and discharge at a rate not less than 3,5 kg/s. The maximum discharge rate shall allow operation by one man. The length of a hand hose line shall not exceed 33 m. Where fixed piping is provided between the powder container and a hand hose line or monitor, the length of piping shall not exceed that length which is capable of maintaining the powder in a fluidised state during sustained or intermittent use, and which can be purged of powder when the system is shut down. Hand hose lines and nozzles shall be of weather-resistant construction or stored in weather resistant housing or covers and be readily accessible.

11.4.6 Hand hose lines shall be considered to have a maximum effective distance of coverage equal to the length of hose. Special consideration shall be given where areas to be protected are substantially higher than the monitor or hand hose reel locations. *See also* LR 11.4.1 regarding topsides process areas.

11.4.7 Ship units fitted with bow, stern load/unload connections shall be provided with independent dry powder units protecting the cargo liquid and vapour piping, aft or forward of the cargo area, by hose lines and a monitor covering the bow, stern load/unload complying with the requirements of 11.4.1 to 11.4.6.

11.4.8 After installation, the pipes, valves, fittings and assembled systems shall be subjected to a tightness test and functional testing of the remote and local release stations. The initial testing shall also include a discharge of sufficient amounts of dry chemical powder to verify that the system is in proper working order. All distribution piping shall be blown through with dry air to ensure that the piping is free of obstructions.

11.5 Enclosed spaces containing cargo handling equipment

11.5.1 Enclosed spaces meeting the criteria of cargo machinery spaces in Ch 1, 1.2.9, and the cargo motor room within the cargo area of any ship unit, shall be provided with a fixed fire extinguishing system complying with the provisions of the FSS Code and taking into account the necessary concentrations/application rate required for extinguishing gas fires.

LR 11.5.1 Cargo machinery spaces shall be protected by an appropriate fire-extinguishing system for the cargo carried. The system is to be approved by the Administration.

11.5.2 The fire risks associated with the turret compartments of any ship unit are to be fully assessed within the installation Fire and Explosion Evaluation (FEE). The fire-fighting/mitigating measures associated with the turret (i.e., water spray, passive fire protection, isolation and blowdown, etc.) are to be based upon the fire risks determined within the Fire and Explosion Evaluation (FEE) and should be in line with the overall installation's fire-fighting and safety philosophy.

11.6 Firefighters' outfits

LR 11.6.1 In addition to the requirements outlined in this Section, further facilities may be required on the installation based on the fire-fighting risks and philosophy derived for the installation via the Fire and Explosion Evaluation (FEE).

11.6.1 Every ship unit shall carry firefighter's outfits complying with the requirements of SOLAS regulation II-2/10.10 as follows:

Total cargo capacity	Number of outfits
5000 m^3 and below	4
Above 5000 m^3	5

11.6.2 Additional requirements for safety equipment are given in Chapter 14.

11.6.3 Any breathing apparatus required as part of a fire-fighter's outfit shall be a self-contained compressed air-operated breathing apparatus having a capacity of at least 1200 l of free air.

Section

12.1 Spaces required to be entered during normal cargo handling operations

The requirements of this Chapter replace the requirements SOLAS Regulations II-2/4.5.2.6 and 4.5.4.1, as amended.

12.1.1 Electric motor rooms, cargo compressor and pump rooms, spaces containing cargo handling equipment and other enclosed spaces where cargo vapours may accumulate shall be fitted with fixed artificial ventilation systems capable of being controlled from outside such spaces. The ventilation shall be run continuously to prevent the accumulation of toxic and/or flammable vapours, with a means of monitoring acceptable to the Administration to be provided. A warning notice requiring the use of such ventilation prior to entering shall be placed outside the compartment.

12.1.2 Artificial ventilation inlets and outlets shall be arranged to ensure sufficient air movement through the space to avoid accumulation of flammable, toxic or asphixiant vapours, and to ensure a safe working environment.

12.1.3 The ventilation system shall have a capacity of not less than 30 changes of air per hour, based upon the total volume of the space. As an exception, non-hazardous cargo control rooms may have eight changes of air per hour.

12.1.4 Where a space has an opening into an adjacent more hazardous space or area, it shall be maintained at an over-pressure. It may be made into a less hazardous space or non-hazardous space by over-pressure protection in accordance with recognised Standards.

12.1.5 Ventilation ducts, air intakes and exhaust outlets serving artificial ventilation systems shall be positioned in accordance with recognised Standards.

12.1.6 Ventilation ducts serving hazardous areas shall not be led through accommodation, service and machinery spaces or control stations, except as allowed in Chapter 16.

12.1.7 Electric motors driving fans shall be placed outside the ventilation ducts that may contain flammable vapours. Ventilation fans shall not produce a source of ignition in either the ventilated space or the ventilation system associated with the space. For hazardous areas, ventilation fans and ducts, adjacent to the fans, shall be of non sparking construction, as defined below:

- *.1* impellers or housing of non-metallic construction, with due regard being paid to the elimination of static electricity;
- *.2* impellers and housing of non-ferrous materials;
- *.3* impellers and housing of austenitic stainless steel; and
- *.4* ferrous impellers and housing with not less than 13 mm design tip clearance.

Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in these places.

12.1.8 Where fans are required by this Chapter, full required ventilation capacity for each space shall be available after failure of any single fan or spare parts shall be provided comprising; a motor, starter spares and complete rotating element, including bearings of each type.

12.1.9 Protection screens of not more than 13 mm square mesh shall be fitted to outside openings of ventilation ducts.

12.1.10 Where spaces are protected by pressurisation the ventilation shall be designed and installed in accordance with recognised Standards.

LR 12.1.1 For 12.1.4, 12.1.5 and 12.1.10 reference is made to the recommendation published by the International Electrotechnical Commission: in particular to the publication IEC 60092-502:1999.

12.2 Spaces not normally entered

Enclosed spaces where cargo vapours may accumulate shall be capable of being ventilated to ensure a safe environment when entry into them is necessary. This shall be capable of being achieved without the need for prior entry.

LR 12.2.1 Ventilation systems are to be capable of use prior to entry and during occupation.
For permanent installations, the capacity of 8 air changes per hour shall be provided and for portable systems, the capacity of 16 air changes per hour.
Fans or blowers shall be clear of personnel access openings, and shall comply with 12.1.7.

LR 12.2.2 Enclosed spaces in the cargo area used as laboratories, workshops, decontamination cubicles or for domestic purposes are to comply with the requirements of 12.1.1.

LR 12.2.3 Particulars of the type and number of portable fans, their arrangements and means of attachment are to be submitted for consideration in relation to the internal and external arrangements of the space concerned.

13.1 General

13.1.1 Where safety applications are to be implemented, the requirements of IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems* or alternative relevant International or National Standard, shall be used. *See* Pt 7, Ch 1, 7.1.15.

13.1.2 Each cargo tank shall be provided with a means for indicating level, pressure and temperature of the cargo. Pressure gauges and temperature indicating devices shall be installed in the liquid and vapour piping systems, in cargo refrigeration installations.

13.1.3 If loading and unloading of the ship unit is performed by means of remotely controlled valves and pumps, all controls and indicators associated with a given cargo tank shall be concentrated in one control position.

13.1.4 Instruments shall be tested to ensure reliability under the working conditions. Test procedures for instruments and the intervals between testing and recalibration shall be in accordance with manufacturer's recommendations, or at a period developed by risk assessment.

13.2 Level indicators for cargo tanks

13.2.1 Each cargo tank shall be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the cargo tank is operational. The device(s) shall be designed to operate throughout the design pressure range of the cargo tank and at temperatures within the cargo operating temperature range.

13.2.2 Where only one liquid level gauge is fitted it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

13.2.3 Cargo tank liquid level gauges may be of the following types, subject to special requirements for particular cargoes shown in column 'g' in the table of Chapter 19:

.1 indirect devices, which determine the amount of cargo by means such as weighing or in-line flow metering;

.2 closed devices, which do not penetrate the cargo tank, such as devices using radio-isotopes or ultrasonic devices;

.3 closed devices, which penetrate the cargo tank, but which form part of a closed system and keep the cargo from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If a closed gauging device is not mounted directly on to the tank, it shall be provided with a shutoff valve located as close as possible to the tank.

.4 restricted devices, which penetrate the tank and when in use permit a small quantity of cargo vapour or liquid to escape to the atmosphere, such as fixed tube and slip tube gauges. When not in use, the devices shall be kept completely closed. The design and installation shall ensure that no dangerous escape of cargo can take place when opening the device. Such gauging devices shall be so designed that the maximum opening does not exceed 1,5 mm diameter or equivalent area unless the device is provided with an excess flow valve.

13.3 Overflow control

13.3.1 Each cargo tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

13.3.2 An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full.

13.3.3 The emergency shutdown valve referred to in 5.5 and 18.10 may be used for this purpose. If another valve is used for this purpose, the same information as referred to in 18.10.2.1.3 shall be available onboard. During loading, whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, alternative arrangements such as limiting the loading rate shall be used.

13.3.4 The position of the sensors in the tank shall be capable of being verified before commissioning. At first loading, and after each dry-docking, testing of high level alarms shall be conducted by raising the cargo liquid level in the cargo tank to the alarm point.

13.3.5 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to cargo operation in accordance with 18.6.2.

13.4 Pressure monitoring

13.4.1 The vapour space of each cargo tank shall be provided with a direct reading gauge. Additionally, an indirect indication is to be provided at the control position required by 13.1.2. Maximum and minimum allowable pressures shall be clearly indicated.

13.4.2 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigating bridge and at the control position required by 13.1.2. Alarms shall be activated before the set pressures are reached.

13.4.3 For cargo tanks fitted with PRVs, which can be set at more than one set pressure in accordance with 8.2.7, high-pressure alarms shall be provided for each set pressure. A permit to work system advising which PRV setting is in use is to be provided.

13.4.4 Each cargo-pump discharge line and each liquid and vapour cargo manifold shall be provided with at least one pressure indicator.

13.4.5 Local-reading manifold pressure indication shall be provided to indicate the pressure between manifold valves of the ship unit and hose connections to the shuttle tanker.

13.4.6 Hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indication.

13.4.7 All pressure indications provided shall be capable of indicating throughout the operating pressure range.

13.5 Temperature indicating devices

13.5.1 Each cargo tank shall be provided with at least two devices for indicating cargo temperatures, one placed at the bottom of the cargo tank and the second near the top of the tank, below the highest allowable liquid level. The lowest temperature for which the cargo tank has been designed, consistent with the assigned class notation, shall be clearly indicated by means of a sign on or near the temperature indicating devices.

13.5.2 The temperature indicating devices shall be capable of providing temperature indication across the expected cargo operating temperature range of the cargo tanks.

13.5.3 Where thermowells are fitted they shall be designed to minimise failure; due to fatigue in normal service.

13.6 Gas detection

13.6.1 Gas detection equipment shall be installed to monitor the integrity of the cargo containment, cargo handling and ancilliary systems in accordance with this Section. However, the overall provision of gas detection on the installation should be defined based on ignition risk mitigating measures and philosophy derived for the installation via the Fire and Explosion Evaluation (FEE).

13.6.2 A permanently installed system of gas detection and audible and visual alarms shall be fitted in:

.1 all enclosed cargo and cargo machinery spaces (including turrets compartments) or similar enclosures containing gas piping, gas equipment or gas consumers;
.2 other enclosed or semi-enclosed spaces where cargo vapours may accumulate including interbarrier spaces and hold spaces for independent tanks other than Type C;
.3 airlocks;
.4 the spaces in gas fired internal combustion engines, referred to in 16.7.3.3;
.5 ventilation hoods and gas ducts required by Chapter 16;
.6 cooling/heating circuits, as required by 7.8.4;
.7 inert gas generator supply headers;
.8 motor rooms for cargo handling machinery.

However, the overall provision of gas detection on the installation should be defined based on ignition risk mitigating measures and philosophy derived for the installation via the Fire and Explosion Evaluation (FEE).

The various fire and gas detectors should feed signals into a robust fire and gas detection system/panel, in accordance with the requirements of Pt 7, Ch 1,2. High level fire and gas signals, along with process hazard signals are then to feed into a robust Emergency Shut-down (ESD) System, in accordance with the requirements of Chapter 18 and Pt 7, Ch 1,7.

13.6.3 Gas detection equipment shall be designed, installed and tested in accordance with IEC 60079-29-1 – *Explosive atmospheres – Gas detectors – Performance requirements of detectors for flammable gases* and shall be suitable for the cargoes to be stored in accordance with column ‘f’ in table of Chapter 19.

13.6.4 For ship units permitted to store non-flammable products, oxygen deficiency monitoring shall be fitted in cargo machinery spaces and cargo tank hold spaces. Furthermore, oxygen deficiency monitoring equipment shall be installed in enclosed or semi-enclosed spaces containing equipment that may cause an oxygen-deficient environment such as nitrogen generators, inert gas generators or nitrogen cycle refrigerant systems.

13.6.5 Permanently installed gas detection shall be of the continuous detection type, capable of immediate response. Where not used to activate safety shutdown functions required by 13.6.7 and Chapter 16, the sampling type detection may be accepted.

13.6.6 When sampling type gas detection equipment is used the following requirements shall be met:

.1 the gas detection equipment shall be capable of continuous monitoring at each sampling head location; and

.2 individual sampling lines from sampling heads to the detection equipment shall be fitted; and

.3 pipe runs from sampling heads shall not be led through non-hazardous spaces except as permitted by 13.6.7.

13.6.7 The gas detection equipment may be located in a non-hazardous space, provided that the detection equipment such as sample piping, sample pumps, solenoids and analysing units are located in a fully enclosed steel cabinet with the door sealed by a gasket. The atmosphere within the enclosure shall be continuously monitored. At gas concentrations of 20 per cent lower flammable limit (LFL) inside the enclosure an alarm shall be activated in accordance with the requirements of 13.6.11 via the fire and gas system. At gas concentrations above 30 per cent lower flammable limit (LFL) inside the enclosure, the gas detection equipment is to be automatically shut down but the alarm in accordance with 13.6.11 is to be maintained until gas concentrations drop below 20 per cent lower flammable limit (LFL) inside the enclosure.

13.6.8 Where the enclosure cannot be arranged directly on the forward bulkhead, sample pipes shall be of steel or equivalent material and are to be routed on their shortest way. Detachable connections, except for the connection points for isolating valves required in 13.6.9 and analysing units, are not permitted.

LR 13.6.1 In liquefied gas storage spaces, including cargo hold spaces, the sampling heads are not to be located where bilge water can collect.

13.6.9 When gas sampling equipment is located in non-hazardous space, a flame arrester and a manual isolating valve shall be fitted in each of the gas sampling lines. The isolating valve shall be fitted on the non-hazardous side. Bulkhead penetrations of sample pipes between hazardous and non-hazardous areas shall maintain the integrity of the division penetrated. The exhaust gas shall be discharged to the open air in a non-hazardous location.

LR 13.6.2 Gas analysing equipment and associated sampling pumps and solenoid valves located in a gas-safe space are to be enclosed in a gastight steel cabinet, monitored by its own sampling point. At gas concentrations of 20 per cent lower flammable limit (LFL) inside the enclosure, an alarm is to be activated in accordance with the requirements of 13.6.11 via the fire and gas system. At gas concentrations above 30 per cent LFL inside the steel cabinet the entire gas analysing unit is to be automatically shut down but the alarm in accordance with 13.6.11 is to be maintained until gas concentrations drop below 20 per cent lower flammable limit (LFL) inside the enclosure.

13.6.10 In every installation, the number and the positions of detection heads shall be determined with due regard to the size and layout of the compartment, the compositions and densities of the products intended to be carried and the dilution from compartment purging or ventilation and stagnant areas.

13.6.11 Any alarms status within a gas detection system required by this Section shall initiate an audible and visible alarm;

.1 on the navigation bridge (if provided on the installation);

.2 at the relevant control station(s) where continuous monitoring of the gas levels is recorded; and

.3 at the gas detector readout location.

13.6.12 In the case of flammable products, the gas detection equipment provided for hold spaces and interbarrier spaces that are required to be inerted shall be capable of measuring gas concentrations of 0 per cent to 100 per cent by volume.

13.6.13 For membrane containment systems, the primary and secondary insulation spaces are to have independent inert gas systems and independent gas detection systems. The alarm in the secondary insulation space shall be set at 30 per cent of the LFL in air, that in the primary space shall be set at a value approved by LR.

13.6.14 For other spaces described by 13.6.2, alarms are to be activated when the vapour concentration reaches a relatively low per cent LFL (typically 20 per cent of the LFL in air). The fire and gas detection system stipulated by Pt 7, Ch 1,2 shall initiate safety functions required by Chapter 18 and Pt 7, Ch 1,7 if the vapour concentration reaches 60 per cent LFL. However, for gas detection within ventilation ducts, a low level alarm setting of 10 per cent of the LFL in air is to be utilised, due to the potential to generate laminar flow within ductwork. Within turbine hoods and other spaces with potential high air change rates, a low level alarm setting of 10 per cent of the LFL shall be utilised with initiation of emergency shut-down actions if vapour concentrations rates 20 per cent of the LFL. The crankcases of internal combustion engines that can run on gas shall be arranged to alarm before 100 per cent LFL.

13.6.15 Gas detection equipment shall be so designed that it may readily be tested. Testing and calibration shall be carried out at regular intervals. Suitable equipment for this purpose shall be carried on board and be used in accordance with the manufacturer's recommendations. Permanent connections for such test equipment shall be fitted.

13.6.16 Every ship unit shall be provided with at least two sets of portable gas detection equipment that meet the requirement of 13.6.3 or an acceptable national or international Standard.

13.6.17 A suitable instrument for the measurement of oxygen levels in inert atmospheres shall be provided.

13.7 Additional requirements for containment systems requiring a secondary barrier

13.7.1 **Integrity of barriers**
Where a secondary barrier is required, permanently installed instrumentation shall be provided to detect when the primary barrier fails to be liquid tight at any location or when liquid cargo is in contact with the secondary barrier at any location. This instrumentation shall consist of appropriate gas detecting devices according to 13.6. However, the instrumentation need not be capable of locating the area where liquid cargo leaks through the primary barrier or where liquid cargo is in contact with the secondary barrier.

13.7.2 **Temperature indication devices**

13.7.2.1 The number and position of temperature indicating devices shall be appropriate to the design of the containment system and cargo operation requirements.

13.7.2.2 When cargo is carried in a cargo containment system with a secondary barrier, at a temperature lower than –55°C, temperature indicating devices shall be provided within the insulation or on the hull structure adjacent to cargo containment systems. The devices shall give readings at regular intervals and, where applicable, alarm of temperatures approaching the lowest for which the hull steel is suitable.

13.7.2.3 If cargo is to be carried at temperatures lower than –55°C, the cargo tank boundaries, if appropriate for the design of the cargo containment system, shall be fitted with a sufficient number of temperature indicating devices to verify that unsatisfactory temperature gradients do not occur.

13.7.2.4 For the purposes of design verification and determining the effectiveness of the initial cooldown procedure, one tank shall be fitted with devices in excess of those required in 13.7.2.1. These devices may be temporary or permanent.

13.8 Automation systems

13.8.1 The requirements of this Section shall apply where automation systems are used to provide instrumented control, monitoring/alarm or safety functions required by this Part.

13.8.2 Automation systems shall be designed, installed and tested in accordance with recognised Standards.

13.8.3 Hardware shall be capable of being demonstrated to be suitable for use in the marine environment by type approval or other means.

13.8.4 Software shall be designed and documented for ease of use, including testing, operation and maintenance.

13.8.5 The user interface shall be designed such that the equipment under control can be operated in a safe and effective manner at all times.

13.8.6 Automation systems shall be arranged such that a hardware failure or an error by the operator does not lead to an unsafe condition. Adequate safeguards against incorrect operation shall be provided.

13.8.7 Appropriate segregation shall be maintained between control, monitoring/alarm and safety functions to limit the effect of single failures. This shall be taken to include all parts of the Automation Systems that are required to provide specified functions, including connected devices and power supplies.

13.8.8 Automation Systems shall be arranged such that the configuration is protected against unauthorised or unintended change.

13.8.9 A management of change process shall be applied to safeguard against unexpected consequences of modification. Records of configuration changes and approvals shall be maintained onboard.

13.8.10 Processes for the development and maintenance of integrated systems shall be in accordance with recognised Standards. These processes shall include appropriate risk identification and management.

13.9 System integration

13.9.1 Essential safety functions shall be designed such that risks of harm to personnel or damage to the installation or the environment are reduced to a level acceptable to the administration, both in normal operation and under fault conditions. Functions shall be designed to fail safe. Roles and responsibilities for integration of systems shall be clearly defined and agreed by all relevant stakeholders.

13.9.2 Functional requirements of each component subsystem shall be clearly defined to ensure that the integrated system meets functional and specified safety requirements and takes account of any limitations of the equipment under control.

13.9.3 Key hazards of the integrated system shall be identified using appropriate risk based techniques.

13.9.4 The integrated system shall have a suitable means of reversionary control.

13.9.5 Failure of one part of the integrated system shall not affect the functionality of other parts except for those functions directly dependent on the defective part.

13.9.6 Operation with an integrated system shall be at least as effective as it would be with individual stand alone equipment or systems.

13.9.7 The integrity of essential machinery or systems, during normal operation and fault conditions, shall be demonstrated.

Section

14.1 Protective equipment

LR 14.1.1 The requirements of this Chapter are not classification requirements. However, in cases where Lloyd's Register (LR) is requested to do so by an Owner, Operator or Duty Holder, the requirements of this Chapter will be applied, together with any amendments or interpretations adopted by the appropriate National Authority.

LR 14.1.2 The requirements of this Chapter are considered to be minimum requirements applicable to installations with bulk liquefied gas storage and/or vapour discharge and loading/offloading manifolds/facilities. However, additional equipment for personnel protection above the requirements outlined within this Chapter may be required on an installation and these should be defined as part of the risk mitigating measures and philosophy derived for the installation.

14.1.1 Suitable protective equipment, including eye protection to a recognised National or International Standard, shall be provided for protection of crew members engaged in normal cargo operations, taking into account the characteristics of the products being carried.

14.1.2 Personal protective and safety equipment required in this chapter shall be kept in suitable, clearly marked lockers located in readily accessible places.

14.1.3 The compressed air equipment shall be inspected at least once a month by a responsible officer and the inspection logged in the ship unit's records. This equipment shall also be inspected and tested by a competent person at least once a year.

14.2 First-aid equipment

14.2.1 A stretcher that is suitable for hoisting an injured person from spaces below deck shall be kept in a readily accessible location.

14.2.2 The ship unit shall have onboard medical first aid equipment, including oxygen resuscitation equipment, based on the requirements of the Medical First Aid Guide (MFAG) for the intended cargoes.

14.3 Safety equipment

14.3.1 Sufficient, but not less than three complete sets of safety equipment shall be provided in addition to the fire-fighter's outfits required by 11.6.1. Each set shall provide adequate personal protection to permit entry and work in a gas-filled space. This equipment shall take into account the nature of the intended cargoes.

14.3.2 Each complete set of safety equipment shall consist of:

.1 one self contained positive pressure air breathing apparatus incorporating full face mask, not using stored oxygen and having a capacity of at least 1 200 litres of free air. Each set shall be compatible with that required by 11.6.1.
.2 protective clothing, boots and gloves to a recognised standard.
.3 steel cored rescue line with belt; and
.4 explosion proof lamp.

14.3.3 An adequate supply of compressed air shall be provided and shall consist of:

.1 At least one fully charged spare air bottle for each breathing apparatus required by 14.3.1, in accordance with the requirements of 11.6.1;
.2 an air compressor of adequate capacity capable of continuous operation, suitable for the supply of high pressure air of breathable quality, and
.3 a charging manifold capable of dealing with sufficient spare breathing apparatus air bottles for the breathing apparatus required by 14.3.1.

15.1 Definitions

15.1.1 **Filling limit (FL)** means the maximum liquid volume in a cargo tank relative to the total tank volume when the liquid cargo has reached the reference temperature.

15.1.2 **Loading limit (LL)** means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

15.1.3 Reference temperature means (for the purposes of this Chapter only):

.1 When no cargo vapour pressure/temperature control, as referred to in Chapter 7, is provided, the temperature corresponding to the vapour pressure of the cargo at the set pressure of the PRVs.

.2 When a cargo vapour pressure/temperature control, as referred to in Chapter 7, is provided, the temperature of the cargo upon termination of loading, during transport or at unloading, whichever is the greatest.

LR 15.1.1 Ambient design temperatures for air and sea-water are at their highest daily mean temperatures for the unit's proposed area of operation based on the 100 year average return period. The ambient temperatures are to be rounded up to the nearest degree Celsius. For initial design, the ambient temperatures may be taken as 45°C for air and 32°C for sea-water.

15.2 General requirements

The maximum filling limit of cargo tanks shall be so determined that the vapour space has a minimum volume at reference temperature allowing for:

.1 tolerance of instrumentation such as level and temperature gauges

.2 volumetric expansion of the cargo between the PRV set pressure and the maximum allowable rise stated in 8.4

.3 an operational margin to account for liquid drained back to cargo tanks after completion of loading, operator reaction time and closing time of valves, *see* 5.5 and 18.10.2.1.4.

15.3 Default filling limit

The default value for the filling limit (FL) of cargo tanks is 98 per cent at the reference temperature. Exceptions to this value shall meet the requirements of 15.4.

15.4 Determination of increased filling limit

15.4.1 A filling limit greater than the limit of 98 per cent specified in 15.3 on condition that, under the trim and list conditions specified in 8.2.17 may be permitted, providing:

.1 no isolated vapour pockets are created within the cargo tank

.2 the PRV inlet arrangement shall remain in the vapour space

.3 allowances need to be provided for:

- *.1* volumetric expansion of the liquid cargo due to the pressure increase from the MARVS to full flow relieving pressure in accordance with 8.4.1
- *.2* an operational margin of minimum 0,1 per cent of tank volume
- *.3* tolerances of instrumentation such as level and temperature gauges.

15.4.2 In no case shall a filling limit exceeding 99,5 per cent at reference temperature be permitted.

15.5 Maximum loading limit

15.5.1 The maximum loading limit (LL) to which a cargo tank may be loaded shall be determined by the following formula:

$$LL = FL \frac{\rho_R}{\rho_L}$$

where:

LL = loading limit as defined in 15.1.2 expressed in per cent;

FL = filling limit as specified in 15.3 or 15.4 expressed in per cent;

ρ_R = relative density of cargo at the reference temperature; and

ρ_L = relative density of cargo at the loading temperature.

15.5.2 The Administration may allow Type C tanks to be loaded according to the formula in 15.5.1 with the relative density ρ_R as defined below, provided that the tank vent system has been approved in accordance with 8.2.18.

ρ_R = relative density of cargo at the highest temperature that the cargo may reach upon termination of loading, during storage, or at unloading, under the ambient design temperature conditions described in LR 15.1.1.

15.6 Information to be provided to the Operator

15.6.1 A document shall be provided to the unit specifying the maximum allowable loading limits for each cargo tank and product, at each applicable loading temperature and maximum reference temperature. The information in this document shall be approved by LR.

15.6.2 Pressures at which the PRVs have been set shall also be stated in the document.

15.6.3 A copy of the above document shall be permanently kept onboard by the Operator.

Section

16.1 General

Except as provided for in 16.9, Methane (LNG) is the only cargo whose vapour or boil off gas may be utilised in machinery spaces of category A, and in these spaces it may be utilised only in systems such as boilers, inert gas generators, internal combustion engines, gas combustion units (GCU) and gas turbines.

LR 16.1.1 In addition to the requirements of this Chapter in respect of using LNG as a fuel, the requirements of Pt 5, Ch 15 are also to be complied with.

LR 16.1.2 The following plans are to be submitted for consideration:

- General arrangement of plan.
- Gas piping systems, together with details of interlocking and safety devices.
- Gas heaters.
- Gas compressors and their prime movers.
- Gas storage pressure vessels.
- Gas and oil fuel burning arrangements.

16.2 Use of cargo vapour as fuel

This section addresses the use of cargo vapour as fuel in systems such as boilers, inert gas generators, internal combustion engines, GCUs and gas turbines.

16.2.1 For vaporised LNG, the fuel supply system shall comply with the requirements of 16.4.1, 16.4.2 and 16.4.3.

16.2.2 For vaporised LNG, gas consumers shall exhibit no visible flame and shall maintain the uptake exhaust temperature below 535°C.

16.3 Arrangement of spaces containing gas consumers

16.3.1 Spaces in which gas consumers are located shall be fitted with a mechanical ventilation system that is arranged to avoid areas where gas may accumulate, taking into account the density of the vapour and potential ignition sources. The ventilation system shall be separated from those serving other spaces.

16.3.2 Gas detectors shall be fitted in these spaces, particularly where air circulation is reduced. The gas detection system shall comply with the requirements of Chapter 13.

16.3.3 Electrical equipment located in the double wall pipe or duct specified in 16.4.3 shall comply with the requirements of Chapter 10.

16.3.4 All vents and bleed lines that may contain or be contaminated by gas fuel shall be routed to a safe location external to the machinery space and be fitted with a flame screen.

16.4 Fuel gas supply

16.4.1 General

The requirements of 16.4 apply to fuel gas supply piping outside of the cargo area. Fuel piping shall not pass through accommodation spaces, service spaces, electrical equipment rooms or control stations. The routeing of the pipeline shall take into account potential hazards due to mechanical damage, such as stores or machinery handling areas. Provision shall be made for inerting and gas-freeing that portion of the gas fuel piping systems located in the machinery space.

16.4.2 Leak detection

Continuous monitoring and alarms shall be provided to indicate a leak in the piping system in enclosed spaces and shut down the relevant gas fuel supply.

16.4.3 Routeing of fuel supply pipes

Fuel piping may pass through or extend into enclosed spaces other than those mentioned in 16.3.1, provided it fulfils one of the following conditions:

.1 A double wall design with the space between the concentric pipes pressurised with inert gas at a pressure greater than the gas fuel pressure. The isolating valve, as required by 16.4.5, closes automatically upon loss of inert gas pressure; or

.2 Installed in a pipe or duct equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes per hour, and shall be arranged to maintain a pressure less than the atmospheric pressure. The mechanical ventilation shall be in accordance with Chapter 12 as applicable. The ventilation shall always be in operation when there is fuel in the piping and the isolating valve, as required by 16.4.5, shall close automatically if the required air flow is not established and maintained by the exhaust ventilation system. The inlet or the duct may be from a non-hazardous machinery space, the ventilation outlet shall be in a safe location.

16.4.4 **Requirements for fuel gas with pressure greater than 1 MPa**

16.4.4.1 Fuel delivery lines between the high pressure fuel pumps/compressor and consumers shall be protected with a double walled piping system capable of containing a high pressure line failure, taking into account the effects of both pressure and low temperature. A single walled pipe in the cargo area up to the isolating valve(s) required by 16.4.6 is acceptable.

16.4.4.2 The arrangement in 16.4.3.2 may also be acceptable providing the pipe or trunk is capable of containing a high pressure line failure, according to the requirements of 16.4.7 and taking into account the effects of both pressure and possible low temperature and providing both inlet and exhaust of the outer pipe or trunk are in the cargo area.

16.4.5 **Gas consumer isolation**

The supply piping of each fuel gas consumer unit shall be provided with fuel gas isolation by automatic double block and bleed, vented to a safe location, under both normal and emergency operation. The automatic valves shall be arranged to fail to the closed position on loss of actuating power. In a space containing multiple consumers, the shutdown of one shall not affect the fuel gas supply to the others.

16.4.6 **Spaces containing gas consumers**

16.4.6.1 If the double barrier around the fuel gas supply system is not continuous due to air inlets or other openings, or if there is any point where single failure will cause leakage into the space, it shall be possible to isolate the fuel gas supply to each individual space with an individual master gas fuel valve, which shall be located within the cargo area.
It shall operate under the following circumstances:

- *.1* Automatically by
  - *.1.1* Gas detection within the space;
  - *.1.2* Leak detection in the annular space of a double walled pipe;
  - *.1.3* Leak detection in other compartments inside the space, containing single walled gas piping;
  - *.1.4* Loss of ventilation in the annular space of the double walled pipe;
  - *.1.5* Loss of ventilation in other compartments inside the space, containing single walled gas piping;
- *.2* Manually from within the space, and at least one remote location.

The isolation of fuel gas supply to a space, shall not affect the fuel gas supply to other spaces containing gas consumers and shall not cause loss of propulsion or electrical power.

16.4.6.2 If the double barrier around the fuel gas supply system is continuous, an individual master valve located in the cargo area may be provided for each gas consumer inside the space. The individual master valve shall operate under the following circumstances:

- *.1* Automatically by:
  - *.1.1* Leak detection in the annular space of a double walled pipe served by that individual master valve;
  - *.1.2* Leak detection in other compartments containing single-walled gas piping that is part of the supply system served by that individual master valve;
  - *.1.3* Loss of ventilation or loss of pressure in the annular space of a double walled pipe;
- *.2* Manually from within the space, and at least one remote location.

16.4.6.3 It shall be possible to isolate the fuel gas supply to each individual space containing a gas consumer(s) with an individual master gas fuel valve, which is located within the cargo area. It shall operate under the following circumstances:

- *.1* Automatically by:
  - *.1.1* Gas detection within the space;
  - *.1.2* Leak detection in the annular space of a double walled space;
  - *.1.3* Loss of ventilation in the annular space of the double walled pipe;
- *.2* Manually from within the space, and at least one remote location.

16.4.6.4 The isolation of fuel gas supply to a space shall not affect the gas supply to other spaces containing gas consumers.

16.4.7 **Piping and ducting construction**

Fuel gas piping in machinery spaces shall comply with 5.1 to 5.9 as applicable. The piping shall, as far as practicable, have welded joints. Those parts of the fuel gas piping that are not enclosed in a ventilated pipe or duct according to 16.4.3, and are on the weather decks outside the cargo area, shall have full penetration butt-welded joints and shall be fully radiographed.

LR 16.4.1 The fuel gas piping in the machinery space is to be tested in place by hydraulic pressure to 7 bar or twice the working pressure, whichever is the greater. Subsequently, the lines are to be tested by air at the working pressure using soapy water, or equivalent, to verify that all joints are absolutely tight.

16.4.8 **Gas detection**

Gas detection systems provided in accordance with the requirements of this chapter shall activate the alarm at <u>a relatively low</u> per cent LFL <u>(typically 20 per cent of the LFL in air)</u> and shut down the master fuel gas valve required by 16.4.6. at not more than 60 per cent LFL. *See also* 13.6.15.

16.5 Fuel gas plant and related storage tanks

16.5.1 **Provision of fuel gas**

All equipment (heaters, compressors, vaporisers, filters, etc.) for conditioning the cargo and/or cargo boil off vapour for its use as fuel, and any related storage tanks, shall be located in the cargo area. If the equipment is in an enclosed space the space shall be ventilated according to 12.1 and be equipped with a fixed fire-extinguishing system, according to 11.5, and with a gas detection system according to 13.6, as applicable.

LR 16.5.1 Provision is to be made to enable the machinery and associated pipework used for preparing and supplying the gas boil-off to be purged of flammable gas prior to being opened up for maintenance or survey.

LR 16.5.2 Gas heaters and compressors, of watertight construction, may be installed on the open deck provided they are suitably located and protected from mechanical damage.

LR 16.5.3 The prime movers for the gas compressors are to be regulated to maintain a positive suction pressure and arranged to stop automatically if the pressure on the suction side of the compressors is lower than 0,035 bar gauge or other approved positive pressure appropriate to the cargo tank system.

LR 16.5.4 The suction and discharge connections to the compressors are to be fitted with isolating valves.

16.5.2 **Remote stops**

16.5.2.1 All rotating equipment utilised for conditioning the cargo for its use as fuel shall be arranged for manual remote stop from the engine room. Additional remote stops shall be located in areas that are always easily accessible, typically cargo control room, navigation bridge where applicable and fire control station.

16.5.2.2 The fuel supply equipment shall be automatically stopped in the case of low suction pressure or fire detection. The requirements of 18.10.1.1 need not apply to fuel gas compressors or pumps when used to supply gas consumers.

16.5.3 **Heating and cooling mediums**
If the heating or cooling medium for the fuel gas conditioning system is returned to spaces outside the cargo area, provisions shall be made to detect and alarm the presence of cargo/cargo vapour in the medium. Any vent outlet shall be in a safe position and fitted with an effective flame screen of an approved type.

16.5.4 **Piping and pressure vessels**
Piping or pressure vessels fitted in the fuel gas supply system shall comply with Chapter 5.

LR 16.5.5 Pressure vessels for storing methane gas are to be of approved design and fitted with pressure relief valves discharging to atmosphere in a safe position.

16.6 Special requirements for main boilers

16.6.1 **Arrangements**

16.6.1.1 Each boiler shall have a separate exhaust uptake.

16.6.1.2 Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

16.6.1.3 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.

16.6.2 **Combustion equipment**

16.6.2.1 The burner systems should be of dual type suitable to burn either:
- oil fuel.
- gas fuel.
- oil and gas fuel simultaneously.

16.6.2.2 Burners shall be designed to maintain stable combustion under all firing conditions.

16.6.2.3 In the event of loss of fuel gas supply an automatic system shall be fitted to change over from fuel gas operation to fuel oil operation without interruption of the boiler firing.

16.6.2.4 Gas nozzles and the burner control system shall be configured such that fuel gas can only be ignited by an established fuel oil flame, unless the boiler and combustion equipment is designed and approved by LR to light on fuel gas.

LR 16.6.1 Oil fuel alone is to be used for starting up. It should be possible to change over easily and quickly from gas to oil fuel operation. These requirements should apply unless otherwise agreed by the Administration. Each boiler is to have a separate uptake to the top of the funnel or a separate funnel.

LR 16.6.2 The firing equipment is to be of combined gas and oil type and be capable of burning both fuels simultaneously. The gas nozzles are to be so disposed as to obtain ignition from the oil flame. An interlocking device is to be provided to prevent the gas fuel supply being opened until the oil and air controls are in the firing position.

16.6.3 **Safety**

16.6.3.1 There shall be arrangements to ensure that fuel gas flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

16.6.3.2 On the pipe of each gas burner a manually operated shut-off valve shall be fitted.

16.6.3.3 Provisions shall be made for automatically purging the fuel gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

16.6.3.4 The automatic fuel changeover system required by 16.6.2.3 shall be monitored with alarms to ensure continuous availability.

16.6.3.5 Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

16.6.3.6 Arrangements shall be made to enable the boilers to be manually purged.

LR 16.6.3 An inert gas or steam purging connection is to be provided on the burner side of the shut-off arrangements so that the pipes to the gas nozzles can be purged immediately before and after methane gas is used for firing purposes.

LR 16.6.4 Each burner supply pipe is to be fitted with a gas shut-off cock and a flame arrester unless this is incorporated in the burner. An audible alarm is to be provided giving warning of loss of minimum effective pressure in the oil fuel discharge line or failure of the fuel pump.

LR 16.6.5 In addition to the low water level fuel shutoff and alarm required by Pt 5, Ch 10,15.7 or 16.7 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) for oil-fired boilers, similar arrangements are to be made for gas shut-off and alarms when the boilers are being gas-fired.

LR 16.6.6 A notice board is to be provided at the firing platform stating:
'If ignition is lost from both oil and gas burners, the combustion spaces are to be thoroughly purged of all combustible gases before relighting the oil burners'.

16.7 Special requirements for gas-fired internal combustion engines

LR 16.7.1 In addition to the requirements for gas-fired internal combustion engines outlined in this Chapter, the requirements of Pt 5, Ch 2 are to be complied with.

Dual fuel engines are those that employ fuel gas (with pilot oil) and fuel oil. Oil fuels may include distillate and residual fuels. Gas only engines are those that employ fuel gas only.

16.7.1 Arrangements

16.7.1.1 When fuel gas is supplied in a mixture with air through a common manifold, flame arrestors shall be installed before each cylinder head.

16.7.1.2 Each engine shall have its own separate exhaust.

16.7.1.3 The exhausts shall be configured to prevent any accumulation of unburnt gaseous fuel.

16.7.1.4 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, then air inlet manifolds, scavenge spaces, exhaust system and crank cases shall be fitted with suitable pressure relief systems. Pressure relief systems shall lead to a safe location, away from personnel.

16.7.1.5 Each engine shall be fitted with vent systems independent of other engines for crankcases, sumps and cooling systems.

16.7.2 Combustion equipment

16.7.2.1 Prior to admission of fuel gas, correct operation of the pilot oil injection system on each unit shall be verified.

16.7.2.2 For a spark ignition engine, if ignition has not been detected by the engine monitoring system within an engine specific time after opening of the gas supply valve, this shall be automatically shut off and the starting sequence terminated. It shall be ensured that any unburned gas mixture is purged from the exhaust system.

16.7.2.3 For dual fuel engines fitted with a pilot oil injection system an automatic system shall be fitted to change over from fuel gas operation to fuel oil operation with minimum fluctuation of the engine power.

16.7.2.4 In the case of unstable operation on engines with the arrangement in 16.7.2.3 when gas firing, the engine shall automatically change to fuel oil mode.

16.7.3 Safety

16.7.3.1 During stopping of the engine the gas fuel shall be automatically shut off before the ignition source.

16.7.3.2 Arrangements shall be provided to ensure that there is no unburnt fuel gas in the exhaust gas system prior to ignition.

16.7.3.3 Crankcases, sumps, scavenge spaces and cooling system vents shall be provided with gas detection. *See* 13.6.15.

16.7.3.4 Provision shall be made within the design of the engine to permit continuous monitoring of possible sources of ignition within the crank case. Instrumentation fitted inside the crankcase shall be in accordance with the requirements of Chapter 10.

16.7.3.5 A means shall be provided to monitor and detect poor combustion or misfiring that may lead to unburnt gas fuel in the exhaust system during operation. In the event that it is detected, the gas fuel supply shall be shut down. Instrumentation fitted inside the exhaust system shall be in accordance with the requirements of Chapter 10.

LR 16.7.4 Additional requirements for gas-fired internal combustion engines and gas turbines

LR 16.7.4.1 Main engines are to be of the dual-fuel type capable of immediate changeover to oil fuel only. All starting is to be carried out on oil fuel alone.

LR 16.7.4.2 Each cylinder is to be provided with its own individual gas inlet valve admitting gas either to the cylinder or to air inlet port. The timing of this valve is to be such that no gas can pass to the exhaust during the scavenge period nor to the inlet port after closure of the air inlet valve.

LR 16.7.4.3 In the event of a fault in the timing mechanism or a cylinder misfire, the exhaust, scavenge and air inlet manifolds are to be protected against the effect of an explosion. Where explosion relief valves are fitted they are to relieve to a safe location.

LR 16.7.4.4 An isolating valve and flame arrester is to be provided at the inlet to the gas supply manifold for each engine. The isolating valve is to be arranged to close automatically in the event of low gas pressure, or failure of any cylinder to fire. Arrangements are to be made so that the gas supply to each engine can be shut off manually from the control position.

LR 16.7.4.5 The crankcase is to be fitted with gas detecting, or equivalent, equipment, and a means for the injection of inert gas. The inert gas injection is to be capable of remote operation from a safe location.
Crankcase relief valves are also to be fitted as required by Pt 5, Ch 2,6 of the Rules for Ships.

16.8 Special requirements for gas turbines

LR 16.8.1 In addition to the requirements for gas turbines outlined in this Chapter, the requirements of Pt 5, Ch 3 are to be complied with.

16.8.1 Arrangements

LR 16.8.1.1 Gas turbines are also to comply with LR 16.7.4.

16.8.1.1 Each turbine shall have its own separate exhaust.

16.8.1.2 The exhausts shall be appropriately configured to prevent any accumulation of unburnt gas fuel.

16.8.1.3 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration of explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be lead to a non-hazardous location, away from personnel.

16.8.2 Combustion equipment

16.8.2.1 An automatic system shall be fitted to change over easily and quickly from fuel gas operation to fuel oil operation with minimum fluctuation of the engine power.

16.8.3 Safety

16.8.3.1 Means shall be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply shall be shut down.

16.8.3.2 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.

16.9 Alternative fuels and technologies

If acceptable to the Administration, other cargo gases may be used as fuel providing that the same level of safety as natural gas in this Part is ensured.
The use of cargoes identified as toxic by the IGC Code shall not be permitted.

16.9.1 For cargoes other than LNG, the fuel supply system shall comply with the requirements of 16.4.1, 16.4.2, 16.4.3 and 16.5, as applicable, and shall include means for preventing condensation of vapour in the system.

16.9.2 Liquefied fuel gas supply systems shall comply with 16.4.5.

16.9.3 In addition to the requirements of 16.4.3.2, both ventilation inlet and outlet shall be in a non-hazardous area external to the machinery space.

LR 16.10 Survey

LR 16.10.1 The gas compressors, heaters, pressure vessels and piping are to be constructed under Special Survey, and the installation of the whole plant on board the ship unit is to be carried out under the supervision of Lloyd's Register's (LR) Surveyors. On completion, the installation is to be tested to prove its capability.

Section

17.1 General

The provisions of this Chapter are applicable where reference is made in column 'i' in the Table of Chapter 19.

17.2 Flame screens on vent outlets

When carrying a cargo referenced to this Section, cargo tank vent outlets shall be provided with readily renewable and effective flame screens or safety heads of an approved type. Due attention shall be paid to the design of flame screens and vent heads, to the possibility of the blockage of these devices by the freezing of cargo vapour or by icing up in adverse weather conditions. Flame screens shall be removed and replaced by protection screens in accordance with 8.2.15 when carrying cargoes not referenced to this Section.

17.3 Cargo pumps and discharge arrangements

17.3.1 The vapour space of cargo tanks equipped with submerged electric motor pumps shall be inerted to a positive pressure prior to loading, during carriage and during unloading of flammable liquids.

17.3.2 The cargo shall be discharged only by deepwell pumps or by hydraulically operated submerged pumps. These pumps shall be of a type designed to avoid liquid pressure against the shaft gland.

17.3.3 Inert gas displacement may be used for discharging cargo from Type C independent tanks provided the cargo system is designed for the expected pressure.

17.4 Carbon dioxide – High purity

17.4.1 Uncontrolled pressure loss from the cargo can cause 'sublimation' and the cargo will change from the liquid to the solid state. The precise 'triple point' temperature of a particular carbon dioxide cargo shall be supplied before loading the cargo, and will depend on the purity of that cargo, and this shall be taken into account when cargo instrumentation is adjusted. The set pressure for the alarms and automatic actions described in this Section shall be set to at least 0,05 MPa above the triple point for the specific cargo being carried. The 'triple point' for pure carbon dioxide occurs at 0,05 MPa and –54,4°C.

17.4.2 There is a potential for the cargo to solidify in the event that a cargo tank relief valve, fitted in accordance with 8.2, fails in the open position. To avoid this, a means of isolating the cargo tank safety valves shall be provided and the requirements of 8.2.9.2 of this Part do not apply when carrying this carbon dioxide. Discharge piping from safety relief valves shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping so the requirements of 8.2.15 of this Part do not apply.

17.4.3 Discharge piping from safety relief valves are not required to comply with 8.2.10, but shall be designed so they remain free from obstructions that could cause clogging. Protective screens shall not be fitted to the outlets of relief valve discharge piping so the requirements of 8.2.15 of this Part do not apply.

17.4.4 Cargo tanks shall be continuously monitoring for low pressure when a carbon dioxide cargo is carried. An audible and visual alarm shall be given at the cargo control position and on the bridge. If the cargo tank pressure continues to fall to within 0,05 MPa of the 'triple point' for the particular cargo, the monitoring system shall automatically close all cargo manifold liquid and vapour valves and stop all cargo compressors and cargo pumps. The emergency shutdown system required by 18.10 of this Part may be used for this purpose.

17.4.5 All materials used in cargo tanks and cargo piping system shall be suitable for the lowest temperature that may occur in service, which is defined as the saturation temperature of the carbon dioxide cargo at the set pressure of the automatic safety system described in 17.4.1.

17.4.6 Cargo hold spaces, cargo compressor rooms and other enclosed spaces where carbon dioxide could accumulate shall be fitted with continuous monitoring for carbon dioxide build-up. This fixed gas detection system replaces the requirements of 13.6 of this Part, and hold spaces shall be monitored permanently even if the ship unit has Type C cargo containment.

17.5 Carbon dioxide – Reclaimed quality

17.5.1 The requirements of 17.4 also apply to this cargo. In addition, the materials of construction used in the cargo system shall also take account of the possibility of corrosion in case the reclaimed quality carbon dioxide cargo contains impurities such as water, sulphur dioxide, etc., which can cause acidic corrosion or other problems.

17.6 Nitrogen

17.6.1 Materials of construction and ancillary equipment such as insulation shall be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system. Due consideration shall be given to venitilation in such areas, where condensation might occur, to avoid the stratification of oxygen-enriched atmosphere.

Section

18.1 General

18.1.1 Those involved in liquefied gas operations are to be made aware of the special requirements associated with, and precautions necessary for, their safe operation.

18.2 Cargo operations manuals

18.2.1 The ship unit shall be provided with copies of suitably detailed cargo system operating manuals approved by the Administration such that trained personnel can safely operate the unit with due regard to the hazards and properties of the cargoes that are permitted to be carried.

18.2.2 The content of the manuals shall include but not be limited to:

.1 Overall operation of the ship unit including procedures for cargo tank cool-down and warm-up, cargo transfer, cargo sampling, gas freeing, ballasting, tank cleaning and changing cargoes;

.2 cargo temperature and pressure control systems;

.3 cargo system limitations, including minimum temperatures (cargo system and inner hull), maximum pressures, cargo transfer rates and filling limits;

.4 nitrogen and inert gas systems;

.5 fire-fighting procedures: operation and maintenance of fire-fighting systems and use of extinguishing agents;

.6 special equipment needed for the safe handling of the particular cargo;

.7 fixed and portable gas detection;

.8 control, alarm and safety systems;

.9 emergency shut-down systems;

.10 procedures to change cargo tank pressure relief valve set pressures in accordance with 8.2.8 and 4.13.1.3;

.11 emergency procedures, including cargo tank relief valve isolation, single tank gas-freeing and entry.

18.3 Cargo information

18.3.1 Information shall be on board and available to all concerned in the form of a cargo information data sheet(s) giving the necessary data for safe cargo operation. Such information shall include, for each product carried:

.1 a full description of the physical and chemical properties necessary for safe cargo operations and containment of the cargo;

.2 reactivity with other cargoes that are capable of being stored.

.3 the actions to be taken in the event of cargo spills or leaks.

.4 countermeasures against accidental personal contact.

.5 fire-fighting procedures and fire-fighting media.

.6 special equipment needed for the safe handling of the particular cargo.

.7 emergency procedures.

18.3.2 The physical data supplied to the Operator, in accordance with 18.3.1.1, shall include information regarding the relative cargo density at various temperatures to enable the calculation of cargo tank filling limits in accordance with the requirements of Chapter 15.

18.3.3 Contingency plans in accordance with 18.3.1.3, for spillage of cargo carried at ambient temperature, shall take account of potential local temperature reduction such as when the escaped cargo has reduced to atmospheric pressure and the potential effect of this cooling on hull steel.

18.4 Suitability for storage

18.4.1 The Operator shall ascertain that the quantity and characteristics of each product to be loaded are within the limits indicated in the Loading and Stability Information booklet provided for in 2.2.5.

18.4.2 Care should be taken to avoid dangerous chemical reactions if cargoes are mixed. This is of particular significance in respect of:

.1 tank cleaning procedures required between successive cargoes in the same tank; and

.2 simultaneous storage of cargoes that react when mixed. This shall be permitted only if the complete cargo systems including, but not limited to, cargo pipework, tanks, vent systems and refrigeration systems, are separated as defined in 1.2.44.

18.5 Storage of cargo at low temperature

When carrying cargoes at low temperatures:

.1 the cool-down procedure laid down for that particular tank, piping and ancillary equipment shall be followed closely.

.2 loading shall be carried out in such a manner as to ensure that design temperature gradients are not exceeded in any cargo tank, piping or other ancillary equipment.

.3 if provided, the heating arrangements associated with the cargo containment systems shall be operated in such a manner as to ensure that the temperature of the hull structure does not fall below that for which the material is designed.

18.6 Cargo transfer operations

18.6.1 A pre cargo operations meeting shall take place between shuttle tanker personnel and the persons responsible at the transfer facility of the ship unit. Information exchanged shall include the details of the intended cargo transfer operations and emergency procedures. A recognised industry checklist shall be completed for the intended cargo transfer and effective communications shall be maintained throughout the operation.

18.6.2 Essential cargo handling controls and alarms shall be checked and tested prior to cargo transfer operations.

18.7 Personnel training

18.7.1 Personnel shall be adequately trained in the operational and safety aspects of the unit. As a minimum:

.1 All personnel shall be adequately trained in the use of protective equipment provided on board and have basic training in the procedures, appropriate to their duties, necessary under emergency conditions.

.2 Crew shall be trained in emergency procedures to deal with conditions of leakage, spillage or fire involving the cargo and a sufficient number of them shall be instructed and trained in essential first aid for the cargoes carried.

18.8 Entry into enclosed spaces

18.8.1 Under normal operational circumstances personnel shall not enter cargo tanks, hold spaces, void spaces, or other enclosed spaces where gas may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and the absence of toxic atmosphere.

18.8.2 If it is necessary to gas-free and aerate a hold space surrounding a Type A cargo tank for routine inspection, and the cargo tank is carrying flammable cargo, the inspection shall be conducted when the tank contains only the minimum amount of cargo ‘heel’ to keep the cargo tank cold. The hold shall be re-inerted as soon as the inspection is completed.

18.8.3 Personnel entering any space designated as a hazardous area on a ship unit carrying flammable products shall not introduce any potential source of ignition into the space unless it has been certified gas free and is maintained in that condition. Portable gas detection equipment must be utilised at all times to ensure personnel safety.

18.9 Cargo sampling

18.9.1 Any cargo sampling shall be conducted under the supervision of an Officer who shall ensure that protective clothing appropriate to the hazards of the cargo is used by everyone involved in the operation.

18.9.2 When taking liquid cargo samples the Officer shall ensure that the sampling equipment is suitable for the temperatures and pressures involved, including cargo pump discharge pressure if relevant.

18.9.3 The Officer shall ensure that any cargo sample equipment used is connected properly to avoid any cargo leakage.

18.9.4 After sampling operations are completed, the Officer shall ensure that any sample valves used are closed properly and the connections used are correctly blanked.

18.10 Linked emergency shutdown (ESD) system

18.10.1 General

18.10.1.1 An emergency shutdown (ESD) system shall be fitted to all ship units to stop cargo flow in the event of an emergency, either internally within the ship unit, or during cargo transfer with shuttle tankers. The design of the ESD system shall avoid the potential generation of surge pressures within cargo transfer pipe work, *see* 18.10.2.1.4. For linked ESD systems the requirements in Pt 7, Ch 1,7.4 are to be satisfied.

18.10.1.2 Auxiliary systems for conditioning the cargo that use toxic or flammable liquids or vapours shall be treated as cargo systems for the purposes of ESD. Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.

Table 18.1 ESD Functional Arrangements

	Pumps		Compressor Systems				Valves	Link
Shut-down action → Initiation ↓	Cargo pumps/cargo booster pumps	Spray/ stripping pumps	Vapour return compressors	Fuel gas compressors and system	Reliquefaction plant****, including condensate return pumps, if fitted	Gas combustion unit	ESD valves	Signal to ship unit-shuttle tanker link *****
Emergency push buttons (*see* 18.10.1.3)	✓	✓	✓	Note 2	✓	✓	✓	✓
Fire detection on deck or in compressor house*	✓	✓	✓	Note 2	✓	✓	✓	✓
High level in cargo tank***	✓	✓	✓	Note 1 Note 2	Note 1	Note 1	Note 4	✓
Signal from ship unit-shuttle tanker link	✓	✓	✓	Note 2	Note 3	n/a	✓	n/a
Loss of motive power to ESD valves**	✓	✓	✓	Note 2	n/a	n/a	✓	✓
Main electric power failure (‘blackout’)	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	✓	✓

NOTES
1. These items of equipment can be omitted from these specific automatic shut-down initiators provided the compressor inlets are protected against cargo liquid ingress.
2. If the fuel gas compressor is used to return cargo vapour to the ship unit, it shall be included in the ESD system only when operating in this mode.
3. If the reliquefaction plant compressors are used for vapour return/ship unit line clearing, they shall be included in the ESD system only when operating in that mode.
4. Alternatively, a stage 1 high level in an individual cargo tank may initiate the closure of the shut-off valve referred to in 13.3.2, and not the ESD valve referred to in 18.10.2.1.3. The sensor indicated in 13.3.2 shall also ensure that when all tank valves referred to in 13.3.2 are shut that the ESD in 18.10.1.3 is operated.
5. These items of equipment shall not be started automatically upon recovery of main electric power and without confirmation of safe conditions.

Remarks
- * Fusible plugs, electronic point temperature monitoring or area fire detection may be used for this purpose on deck.
- ** Failure of hydraulic, electric or pneumatic power for remotely operated ESD valve actuators.
- *** *See* 13.3.2 and 13.3.3.
- **** Indirect refrigeration systems using an inert medium, such as nitrogen, need not be included in the ESD function.
- ***** Signal need not indicate the event initiating ESD.
- ✓ Functional requirement.
- n/a Not applicable.

18.10.2 **ESD valve requirements**

18.10.2.1 **General**

18.10.2.1.1 The term ESD valve means any valve operated by the ESD system.

18.10.2.1.2 ESD valves shall be remotely operated, be of the fail closed type (closed on loss of actuating power), shall be capable of local manual closure and have positive indication of the actual valve position. As an alternative to the local manual closing of the ESD valve, a manually operated shut-off valve in series with the ESD valve shall be permitted. The manual valve shall be located adjacent to the ESD valve. Provisions shall be made to handle trapped liquid should the ESD valve close while the manual valve is also closed.
A manually operated vent valve in the pneumatic/hydraulic logic is preferable to an additional in-line valve.

18.10.2.1.3 ESD valves in liquid piping systems shall close fully and smoothly within 30 seconds of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

18.10.2.1.4 The closing time of the valve referred to in 13.3.1 to 13.3.3 (i.e., time from shut-down signal initiation to complete valve closure) shall not be greater than:

$$\frac{3600U}{LR}$$

where

U = ullage volume at operating signal level (m^3)
LR = maximum loading rate agreed between ship unit and shuttle tanker (m^3/h).

The loading rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the loading hose or arm and the piping systems of the ship unit and shuttle tanker where relevant.

18.10.2.2 **Ship unit-shuttle tanker manifold connections**
One ESD valve shall be provided at each manifold connection. Cargo manifold connections not being used for transfer operations shall be blanked with blank flanges rated for the design pressure of the pipeline system.

18.10.2.3 **Cargo system valves**
If cargo system valves as defined in 5.5 are also ESD valves within the meaning of 18.10, then the requirements of 18.10 will apply.

18.10.3 **ESD system controls**

18.10.3.1 As a minimum, the ESD system shall be capable of manual operation by a single control in the control position required by 13.1.2 or the cargo control room if installed, and no less than two locations in the cargo area.

18.10.3.2 The ESD shall be automatically activated on detection of a fire on the weather decks of the cargo area and/or cargo machinery spaces. As a minimum, the method of detection used on the weather decks should cover the liquid and vapour domes of the cargo tanks, the cargo manifolds and areas where liquid piping is dismantled regularly.

18.10.3.3 The ESD system shall be activated by the manual and automatic inputs listed in Table 18.1. Any additional inputs should only be included in the ESD system if it can be shown their inclusion does not reduce the integrity and reliability of the system overall.

18.10.4 **Additional shut-downs**

18.10.4.1 The requirements of 8.3.1.1 to protect the cargo tank from external differential pressure may be fulfilled by using an independent low pressure trip to activate the ESD system, or as a minimum to stop any cargo pumps or compressors.

18.10.4.2 An input to the ESD system from the overflow control system required by 13.3 may be provided to stop any cargo pumps or compressors running at the time a high level is detected, as this alarm may be due to inadvertent internal transfer of cargo from tank to tank.

18.10.5 **Pre-operations testing**
Cargo emergency shut-down and alarm systems involved in cargo transfer shall be checked and tested before cargo handling operations begin.

18.11 Hot work on or near cargo containment systems

18.11.1 Special fire precautions shall be taken in the vicinity of cargo tanks and particularly insulation systems that may be flammable or contaminated with hydrocarbons or that may give off toxic fumes as a product of combustion.

18.12 Additional operating requirements

Additional operating requirements will be found in the following paragraphs of this Part 2.2.2, 2.2.5, 2.2.6, 3.8.3, 3.8.4, 5.3.2, 5.3.3.3, 5.7.3, 7.1, 8.2.7, 8.2.8, 8.2.9, 9.2, 9.3, 9.4.4, 12.1.1, 13.1.3, 13.3.5, 13.6.16, 14.3.3, 15.3, 15.6, 16.6.3.

19.1 Explanatory notes to the summary of minimum requirements

Product name (column a)	
UN Number (column b)	
Ship type (column c)	Ship unit type 2G, *see* Chapter 2
Independent tank type C required (column d)	– not required under the IGC Code
Tank environmental control (column e)	– no special requirements under the IGC Code
Vapour detection (column f)A:	F: Flammable vapour detection Asphixiant
Gauging (column g)	R: Indirect, closed or restricted, *see* Chapter 13 C: indirect or closed, *see* Chapter 13
MFAG Table no. (column h)	MFAG numbers are provided for information on the emergency procedures to be applied in the event of an accident involving the products covered by the IGC Code Where any of the products listed are carried at low temperature from which frostbite may occur, MFAG no. 620 is also applicable
Special requirements (column i)	When specific reference is made to Chapter 17, these requirements shall be additional to the requirements in any other column

a Product name	b UN number	c Ship unit type	d Independent tank type C required	e Control of vapour space within cargo tanks	f Vapour detection	g Gauging	h MFAG Table no.	i Special requirements
Butane	1011	2G	—	—	F	R	310	—
Butane-propane mixture	1011/1978	2G	—	—	F	R	310	—
Carbon dioxide (High Purity)	—	2G *see* Note 1	—	—	A	R	—	17.4
Carbon dioxide (Reclaimed Quality)	—	2G *see* Note 1	—	—	A	R	—	17.5
Ethane	1961	2G	—	—	F	R	310	—
Methane (LNG)	1972	2G	—	—	F	C	620	—
Nitrogen	2040	2G *see* Note 1	—	—	A	C	—	17.6
Pentane (all isomers) *see* Note 2	1265	2G	—	—	F	R	310	17.2, 17.3
Propane	1978	2G	—	—	F	R	310	—

LR NOTES
1. Ship units designed to store LNG or LPG with additional tanks to store carbon dioxide are to comply with the requirements for ship unit type 2G.
2. This cargo is also covered by the *International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk* (IBC Code).

1 General

The guidance given in this Appendix is in addition to the requirements of 4.19 where applicable to non-metallic materials.

The manufacture, testing, inspection and documentation of non-metallic materials shall in general comply with recognised Standards, and with the specific requirements of this Part as applicable.

When selecting a non-metallic material, the designer must ensure it has properties appropriate to the analysis and specification of the system requirements. A material can be selected to fulfil one or more requirements.

A wide range of non-metallic materials may be considered. Therefore the section below on material selection criteria cannot cover every eventuality and must be considered as guidance.

2 Material selection criteria

Non-metallic materials may be selected for use in various parts of liquefied gas carrier cargo systems based on consideration of the following basic properties:

Insulation – the ability to limit heat flow

Load bearing – the ability to contribute to the strength of the containment system

Tightness – the ability to provide liquid and vapour tight barriers

Joining – the ability to be joined (for example by bonding, welding or fastening).

Additional considerations may apply, depending on the specific system design.

3 Properties of materials

3.1 Flexibility of insulating material

The ability of an insulating material to be bent or shaped easily without damage or breakage.

3.2 Loose fill material

A homogeneous solid, generally in the form of fine particles, such as a powder or beads, normally used to fill the voids in an inaccessible space to provide an effective insulation.

3.3 Nanomaterial

A material with properties derived from its specific microscopic structure.

3.4 Cellular material

A material type containing cells that are either open, closed or both and which are dispersed throughout its mass.

3.5 Adhesive material

A product that joins or bonds two adjacent surfaces together by an adhesive process.

3.6 Other materials

Materials that are not characterised in this section of the Part shall be identified and listed. The relevant tests used to evaluate the suitability of material for use in the cargo system shall be identified and documented.

4 Material selection and testing requirements

4.1 Material specification

When the initial selection of a material has been made, tests are to be conducted to validate the suitability of this material for the use intended.

The material used shall clearly be identified and the relevant tests shall be fully documented.

Materials shall be selected according to their intended use. They shall:

- be compatible with all the products that may be carried
- not be contaminated by any cargo nor react with it
- not have any characteristics or properties affected by the cargo and
- be capable to withstand thermal shocks within the operating temperature range.

4.2 Material testing

The tests required for a particular material depend on the design analysis, specification and intended duty. The list of tests below is for illustration. Any additional tests required, for example in respect of sliding, damping and galvanic insulation, shall be identified clearly and documented.

Materials selected according to 4.1 of this Appendix shall be tested further according to Table A1.4.1.

Thermal shock testing should submit the material and/or assembly to the most extreme thermal gradient it will experience when in service.

Table A1.4.1 Material testing

Mechanical tests		X		X
Tightness tests			X	
Thermal tests	X			
Physical tests (*see* 6.9.2.5)				

4.2.1 **Inherent properties of materials**

Tests shall be carried out to ensure that the inherent properties of the material selected will not have any negative impact in respect of the use intended.

For all selected materials, the following properties shall be evaluated:

- Density; example Standard ISO 845
- Linear coefficient of thermal expansion (LCTE); example Standard ISO 11359 across the widest specified operating temperature range. However, for loose fill material, the volumetric coefficient of thermal expansion (VCTE) shall be evaluated as this is more relevant.

Irrespective of their inherent properties and intended duty, all materials selected shall be tested for the design service temperature range down to 5°C below the minimum design temperature, but not lower than –196°C.

Each property evaluation test shall be performed in accordance with recognised Standards. Where there are no such standards, the test procedure proposed shall be fully detailed and submitted to the Administration for acceptance. Sampling shall be sufficient to ensure a true representation of the properties of the material selected.

4.2.2 **Mechanical tests**

The mechanical tests shall be performed in accordance with Table A1.4.2.

Table A1.4.2 Mechanical tests

Mechanical tests	Load bearing structural
Tensile	ISO 527 ISO 1421 ISO 3346 ISO 1926
Shearing	ISO 4587 ISO 3347 ISO 1922 ISO 6237
Compressive	ISO 604 ISO 844 ISO 3132
Bending	ISO 3133 ISO 14679
Creep	ISO 7850

If the chosen function for a material relies on particular properties such as tensile, compressive and shear strength, yield stress, modulus or elongation, these properties shall be tested to a recognised Standard. If the properties required are assessed by numerical simulation according to a high order behaviour law, the testing shall be performed to the satisfaction of the Administration.

Creep may be caused by sustained loads, for example cargo pressure or structural loads. Creep testing shall be conducted based on the loads expected to be encountered during the design life of the containment system.

4.2.3 **Tightness tests**

The tightness requirement for the material shall relate to its operational functionality.

Tightness tests shall be conducted to give a measurement of the material's permeability in the configuration corresponding to the application envisaged (e.g., thickness and stress conditions) using the fluid to be retained (e.g., cargo, water vapour or trace gas).

The tightness tests shall be based on the tests indicated as examples in Table A1.4.3.

Table A1.4.3 Tightness tests

Tightness tests	Tightness
Porosity/Permeability	ISO 15106 ISO 2528 ISO 2782

4.2.4 **Thermal conductivity tests**

Thermal conductivity tests shall be representative of the lifecycle of the insulation material so its properties over the design life of the cargo system can be assessed. If these properties are likely to deteriorate over time, the material shall be aged as best as possible in an environment corresponding to its lifecycle, for example, operating temperature, light, vapour and installation (e.g., packaging, bags, boxes, etc).

Requirements for the absolute value and acceptable range of thermal conductivity and heat capacity shall be chosen taking into account the effect on the operational efficiency of the cargo containment system. Particular attention should also be paid to the sizing of the associated cargo handling system and components such as safety relief valves plus vapour return and handling equipment.

Thermal tests shall be based on the tests indicated as examples in Table A1.4.4 or their equivalents.

Table A1.4.4 Thermal conductivity tests

Thermal tests	Insulting
Thermal conductivity	ISO 8301 ISO 8302
Heat capacity	x

4.2.5 **Physical tests**

In addition to the requirements of 4.19.2.3 and 4.19.3.2, Table A1.4.5 provides guidance and information on some of the additional physical tests that may be considered.

Table A1.4.5 Physical tests

Physical tests	Flexible insulating	Loose fill	Nanomaterial	Cellular	Adhesive
Particle size		x			
Closed cells content				ISO 4590	
Absorption/desorption	ISO 12571	x		ISO 2896	
Absorption/desorption			x		
Viscosity					ISO 2555 ISO 2431
Open time					ISO 10364
Thixotropic properties					x
Hardness					ISO 868

Requirements for loose fill material segregation shall be chosen considering its potential adverse effect on the material properties (density, thermal conductivity) when subjected to environmental variations such as thermal cycling and vibration.
Requirements for a materials with closed cell structures shall be based on its eventual impact on gas flow and buffering capacity during transient thermal phases.
Similarly, adsorption and absorption requirements shall take into account the potential adverse effect an uncontrolled buffering of liquid or gas may have on the system.

5 Quality control and quality assurance (QA/QC)

5.1 General

Once a material has been selected, after testing as outlined in Section 4 of this Appendix, a detailed quality assurance/quality control (QA/QC) programme shall be applied to ensure the continued conformity of the material during installation and service. This programme shall consider the material starting from the manufacturer's quality manual (QM) and then follow it throughout the construction of the cargo system.
The QA/QC programme shall include the procedure for fabrication, storage, handling and preventive actions to guard against exposure of a material to harmful effects. These may include, for example, the effect of sunlight on some insulation materials or the contamination of material surfaces by contact with personal products such as hand creams.

LR A1.5.1 The proposed procedure is to be submitted to LR for consideration. All other materials in the containment system are also to be considered and included in the aforementioned procedure.

The sampling methods and the frequency of testing in the QA/QC programme shall be specified to ensure the continued conformity of the material selected throughout its production and installation.
Where powder or granulated insulation is produced, arrangements should be made to prevent compacting of the material due to vibrations.

5.2 QA/QC during component manufacture

The QA/QC program in respect of component manufacture must include, as a minimum but not limited to, the following items:

5.2.1 Component identification

For each material, the manufacturer shall implement a marking system to clearly identify the production batch. The marking system shall not interfere in any way with the properties of the product.
This marking system shall ensure complete traceability of the component and shall include:

- Date of production and potential expiration date
- Manufacturer's references
- Reference specification
- Reference order
- When necessary, any potential environmental parameters to be maintained during transportation and storage.

5.2.2 Production sampling and audit method

Regular sampling is required during production to ensure the quality level and continued conformity of a selected material. The frequency, the method and the tests to be performed shall be defined in QA/QC program; for example, these tests will usually cover, *inter alia*, raw materials, process parameters and component checks.
Process parameters and results of the production QC tests shall be in strict accordance with those detailed in the QM for the material selected.
The objective of the audit method as described in the QM is to control the repeatability of the process and the efficacy of the QA/QC program.
During auditing, Auditors shall be provided with free access to all production and QC areas. Audit results must be in accordance with the values and tolerances as stated in the relevant QM.

6 Bonding and joining process requirement and testing

6.1 Bonding procedure qualification

The Bonding Procedure Specification and Qualification Test should be defined in accordance with an appropriate recognised Standard.

The bonding procedures shall be fully documented before work commences to ensure the properties of the bond are acceptable.

The following parameters are to be considered when developing a specification:

- surface preparation
- materials storage and handling prior to installation
- covering time
- open time
- mixing ratio, deposited quantity
- environmental parameters (temperature, humidity)
- curing pressure, temperature and time.

Additional requirements are to be included if necessary to ensure acceptable results.

The bonding procedures specification shall be validated by an appropriate procedure qualification testing programme.

6.2 Personnel qualifications

Personnel involved in bonding processes shall be trained and qualified to recognised Standards.

Regular tests shall be made to ensure the continued performance of people carrying out bonding operations to ensure a consistent quality of bonding.

7 Production bonding tests and controls

7.1 Destructive testing

During production, representative samples shall be taken and tested to check they correspond to the required level of strength as required for the design.

7.2 Non-destructive testing

During production, tests which are not detrimental to bond integrity shall be performed using an appropriate technique such as:

- visual examination
- internal defects detection (for example acoustic, ultrasonic or shear test
- local tightness testing.

If the bonds have to provide tightness as part of their design function, a global tightness test of the cargo containment system shall be completed after the end of the erection in accordance with the designer's and QA/QC programme.

The QA/QC standards shall include acceptance standards for the tightness of the bonded components when built and during the lifecycle of the containment system.

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